AD-A190 777 COMPUTING BASIC SOLAR AND LUNAR DATA FROM THE AIR ALMANAC(U) WEATHER WING (5TH) LANGLEY AFB VA J K SANDERS ET AL DEC 87 5WW-TN-87-001 1/1

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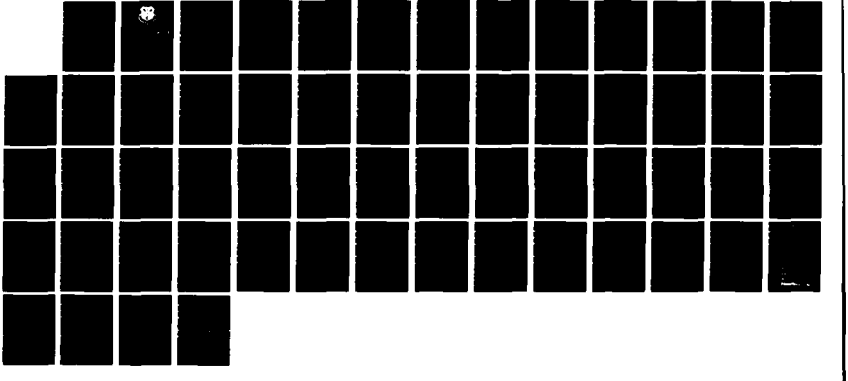

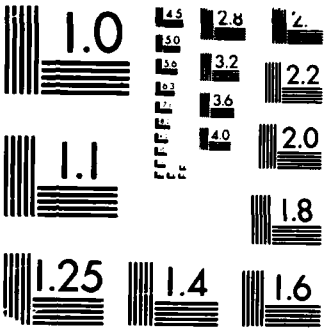

5WW/TN-87/001

5TH WEATHER WING TECHNICAL NOTE

COMPUTING BASIC SOLAR AND LUNAR DATA FROM THE AIR ALMANAC

December 1987

5WW/DNC

Abstract: This Technical Note provides programmed instruction on the us of the Air Almanac to compute times of sunrise, sunset, moonrise, moonset, and duration of civil twilight for any location between latitudes 60°S and 90°N. Appropriate basic astronomy is included. This Technical Note updates and supersedes 5WW/TN-79/002.

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Update by - MSgt George T. Gilligan Jr.

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COMPUTING BASIC LIGHT DATA FROM THE AIR ALMANAC

INTRODUCTION

A pilot comes into your weather office and asks for the time of sunset at his destination; or perhaps you're out in the field and have no access to a computer or some other means of computing astronomical data. How can you provide this information using the Air Almanac?

This Tech Note, which has been reviewed by the Nautical Almanac Office. U.S. Naval Observatory, describes the procedures for extracting these data from the Air Almanac. It will also describe basic theories and laws governing these phenomena. A frame-by-frame programmed learning approach is used.

The Air Almanac is published annually by the Naval Observatory, and is available from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402. Note: AWS units should obtain the Almanac using procedures defined in AWSR 7-1.

The tables and graphs reproduced in this Tech Note are from the Air Almanac 1987 edition; consequently the data, table numbers and page numbers will not necessarily agree with another edition. The procedures for extracting the data are the same, regardless of the edition used.

To complete some of the calculations you will need a few sheets of scratch paper, both to cover the answers (which follow the questions) and to make calculations. A clear plastic straight edge, and in some cases either a pocket calculator or trigonometric tables will also be needed .

The following publications were used in preparing this Tech Note:
a. AFM 51-40, 1983, Air Navigation , Chaps 9-10.
b. The Air Almanac, U. S. Naval Observatory, U. S. Government Printing Office, Washington D.C., 1987.

Upon completion of the Program you should be able to extract the data necessary to support your mission directly from the Air Almanac. You can use a worksheet similar to the one provided at the end of this text, to make the extraction of data easier. ED.Note: The worksheet was based on an idea of SMSgt Depew of 25 Wea Sq. He had developed a similar worksheet, which was distributed for use to his subordinate units.

LEARNING OBJECTIVES

1. State the main reason why sunrise, sunset and twilight times change from day-to-day.

2. Name two factors that cause moonrise/set times to change from day to day.

3. Given a date and a position between 72 Deg. N. and 60 Deg. S, obtain the times of sunrise/set, moonrise/set, and morning and evening civil twilights in either Universal Time (Greenwich Mean Time), Local Mean Time, Local Standard and/or Daylight Savings Time, by using the tables in the Air Almanac.

4. Given a date and a position between 65 Deg. N. and 90 Deg. N, obtain the times of sunrise/set, moonrise/set, and morning and evening civil twilights in either Universal Time (Greenwich Mean Time), Local Mean Time, Local Standard and/or Daylight Savings Time, by using the tables in the Air Almanac.

5. Given a location, date and time, calculate the azimuth and altitude of the sun.

PROGRAMMED LEARNING TEXT

FRAME 1

In order to utilize the Air Almanac to find Sunrise/set, and twilight times for your given location you should have some background as to why these times vary both on a daily basis and also latitudinally. The main reason the sun does not rise at the same time every day is the fact that the earth's axis is tilted with respect to it's orbital plane. There are other factors such as, the earth's elliptical orbit and it's wobble at the, poles but this only contributes a few minutes to the annual variation. However, it is the tilt of the axis that causes the seasons and the extremes in the lengths of daylight and darkness.

In the illustration of the earth and its orbit (Figure 1), the 21 December (winter solstice) and 21 June (summer solstice) earth representations have been enlarged to show the extremes in length of daylight caused by first one pole, then the other being tilted toward the sun. Notice in the enlargements that the length of daylight varies with latitude. On 21 June, for example, the length of daylight becomes progressively shorter as you move from north to south.

The axis remains tilted in the same direction as the earth moves in its orbit around the sun. This causes the length of daylight at any one location to vary from day to day. On 21 March (spring equinox) and 21 September (autumnal equinox), the axis' tilt is in a plane perpendicular to the sun's rays, and the durations of daylight and darkness are about 12 hours each for all latitudes.

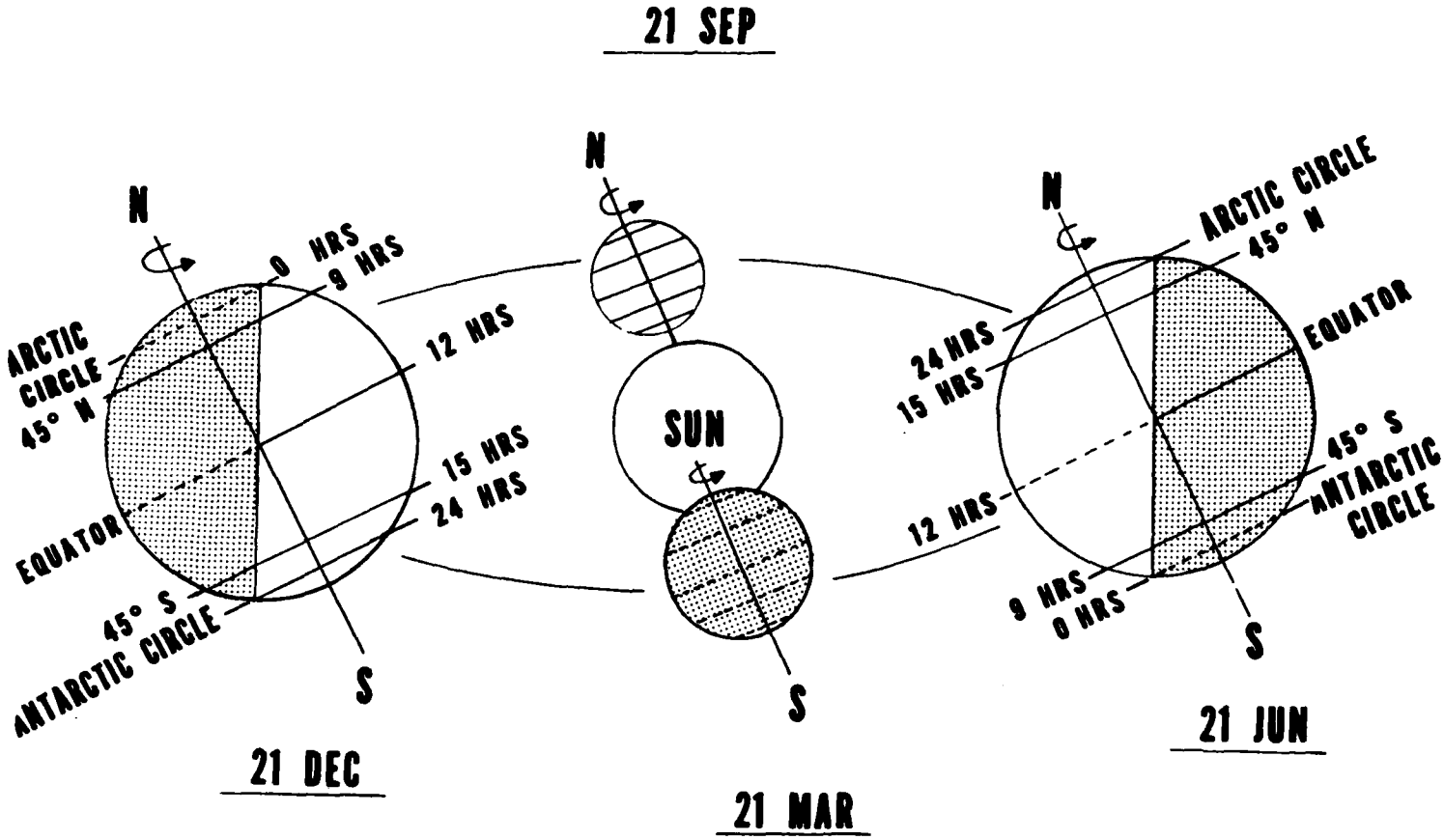


Figure 1. ILLUSTRATION OF EARTH'S ORBIT AND EFFECTS OF TILTED AXIS UPON LENGHT OF DAY (DATES VARY SLIGHTLY FROM YEAR TO YEAR).

Using the illustration, (Figure 1) state the approximate duration of daylight for the latitude 45° N. on the following dates:

A. 21 December _____

B. 21 March _____

C. 21 June _____

D. 21 September _____

****

ANSWER:

A. 9 hours

B. 12 hours

C. 15 hours

D. 12 hours

FRAME 2

The main reason that the times of sunrise/set, and the begin/end times of the twilights vary is because:

__ A. of the obliquity of the ecliptic

__ B. the poles wobble.

__ C. the earth's orbit is an ellipse.

__ D. the earth's axis is tilted 23 1/2° with respect to the plane of the earth's orbit.

****

ANSWER:

X D.

FRAME 3

The earth's axis tilt and other factors are taken into consideration by the Naval Observatory when they compute the times of sunrise/set and twilights, which are published in the Air Almanac. The published Almanac times are Greenwich Mean Time (GMT) or they are also called Universal Time (UT). "Mean time" is based on the assumption that the earth rotates about its axis at a constant velocity (actual changes from one day to the next are very slight) Because of this assumption, it's possible to establish the following relationship between time and the earth's rotation:

TIME	ARC
24 hours	360°
1 hour	15°
4 minutes	1°

Thus in two hours the sun will appear to pass through an arc of 30°. Greenwich Mean Time (GMT) is mean time measured with respect to the Greenwich Meridian (See Figure 2.) At 0000 GMT, the sun (to be correct we should say the "mean sun") is directly above the longitude opposite from Greenwich, i.e.; 180° from Greenwich, and at 1200 GMT the mean sun is directly above the Greenwich longitude. Local Mean Time is similar to GMT except it is measured with respect to your local position. At 0000 LMT the mean sun is directly above your longitude.

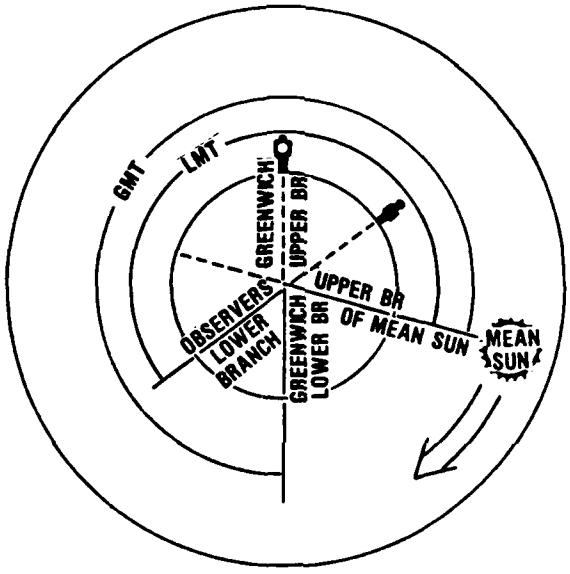


Figure 2. Measuring Greenwich Mean Time (GMT).

LMT is not useful to regulate our daily activities because it varies continuously with longitude since it is based on the position of the observer. LMT is useful in solar calculations because "for all places of the same latitude the corresponding phenomena will occur at approximately the same Local Mean Time (L.M.T.) and this will be approximately the same GMT. tabulated (Ed. Note. in the Air Almanac), since GMT. = L.M.T. at Greenwich. The disadvantage of using LMT to regulate our daily activities was overcome by the introduction of zone time. The world has been divided into 24 zones, each zone being 15° (or one hour) wide. Each zone uses the LMT of its central meridian as the standard time (local standard time (LST)) for the zone.

Below is a a replica of the list of contents (Figure 3) taken from an Air Almanac. The tables and graphs used in this programmed text have been underlined.

LIST OF CONTENTS

Figure 3. Air Almanac List of Contents

NO RESPONSE NECESSARY

FRAME 4

In the sunrise/set, and twilight tables the times are listed in Local Mean Time (LMT) for every third day for the specific latitudes shown at the side of the table. When there is less than a three minute change between the days listed, simply use the time listed for the nearest date. If the change is three minutes or more, you must interpolate for the date required. You must also interpolate between latitudes, if your latitude of interest is not listed.

Using the sample sunrise table in Figure 4, find the times (LMT) of sunrise for the following dates and latitudes:

A. 3 December, 50° N. _____

B. 13 December, 20° S. _____

C. 29 November, 59° N. _____

D. 1 December, 23° N. _____

A144 SUNRISE

Lat.	November				December											Jan.
	19	22	25	28	1	4	7	10	13	16	19	22	25	28	31	3
N 72	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m
70	10 13	10 38	11 15	—	—	—	—	—	—	—	—	—	—	—	—	—
68	09 29	09 43	09 59	10 15	10 32	10 50	11 12	—	—	—	—	—	—	—	—	—
66	09 00	09 11	09 22	09 33	09 44	09 55	10 04	10 13	10 21	10 28	10 32	10 35	10 35	10 34	10 30	10 26
64	08 38	08 47	08 56	09 05	09 14	09 22	09 29	09 36	09 42	09 46	09 50	09 52	09 53	09 53	09 51	09 48
62	20	29	37	08 44	08 51	08 58	09 04	09 10	09 15	09 19	21	24	25	25	24	22
N 60	08 06	08 13	08 20	08 27	08 33	08 39	08 45	08 50	08 54	08 57	09 00	09 02	09 03	09 03	09 03	09 02
58	07 54	08 00	08 07	13	18	24	29	33	37	40	08 43	08 45	08 46	08 46	08 46	08 45
56	43	07 49	07 55	08 00	08 06	08 11	15	19	22	25	28	30	31	32	32	31
54	34	39	44	07 50	07 54	07 59	08 03	08 07	08 10	13	15	17	18	19	19	19
52	26	31	35	40	44	49	07 52	07 56	07 59	08 02	08 04	08 06	08 07	08 08	08 08	08 08
N 50	07 18	07 23	07 27	07 32	07 36	07 40	07 43	07 46	07 49	07 52	07 54	07 56	07 57	07 58	07 58	07 58
45	07 02	07 06	07 10	07 14	17	21	24	27	29	32	34	35	36	37	38	38
40	06 49	06 52	06 56	06 59	07 02	07 05	07 08	07 10	07 12	15	17	18	20	21	22	22
35	38	40	43	46	06 49	06 51	06 54	06 56	06 59	07 01	07 03	07 04	07 06	07 07	07 08	07 08
30	28	30	33	35	38	40	42	45	47	06 48	06 50	06 52	06 53	06 54	06 55	06 56
N 20	06 11	06 13	06 14	06 16	06 18	06 20	06 22	06 24	06 26	06 27	06 29	06 31	06 32	06 33	06 35	06 36
N 10	05 56	05 57	05 58	06 00	06 01	06 03	06 04	06 06	06 07	06 09	06 10	06 12	06 13	06 15	06 16	17
0	42	42	43	05 44	05 45	05 46	05 47	05 49	05 50	05 52	05 53	05 55	05 56	05 58	05 59	06 00
S 10	28	28	28	28	29	30	31	32	33	34	35	37	38	40	42	05 43
20	05 12	05 12	05 11	05 11	05 12	05 12	05 12	05 13	05 14	05 15	05 17	05 18	05 20	05 21	23	25
S 30	04 54	04 53	04 52	04 52	04 51	04 51	04 51	04 52	04 52	04 53	04 54	04 56	04 57	04 59	05 01	05 03
35	44	42	41	40	40	39	39	39	40	40	42	43	44	46	04 48	04 51
40	32	30	28	27	26	25	25	25	25	25	26	28	29	31	33	36
45	18	04 15	04 13	04 11	04 09	04 08	04 07	04 07	04 07	04 07	04 08	04 10	04 11	04 13	04 16	04 18
50	04 01	03 57	03 54	03 52	03 49	03 48	03 46	03 45	03 45	03 45	03 46	03 47	03 49	03 51	03 54	03 57
S 52	03 52	03 49	03 45	03 42	03 40	03 38	03 36	03 35	03 34	03 34	03 35	03 36	03 38	03 40	03 43	03 46
54	43	39	35	32	29	26	24	23	22	22	23	24	26	28	31	34
56	33	28	24	20	16	03 13	03 11	03 10	03 09	03 08	03 09	03 10	03 11	03 14	17	20
58	21	16	03 10	03 06	03 02	02 58	02 56	02 54	02 52	02 52	02 52	02 53	02 55	02 57	03 00	03 04
S 60	03 07	03 01	02 55	02 49	02 45	02 40	02 37	02 34	02 32	02 31	02 31	02 32	02 34	02 37	02 40	02 45

FIGURE 4. SAMPLE SUNRISE TABLE

NOTE: For the northernmost latitudes on this and similar tables you will see a number of symbols used. The symbols and their meanings are as follows:

 Sun continuously above the horizon.

 Sun continuously below the horizon.

//// Twilight lasts all night.

****

ANSWER:

A. 0739 LMT

B. 0514 LMT

C. 0823 LMT

D. 0624 LMT

°	h m	°	h m	°	h m	°	h m	°	h m	°	h m	′	m s
0	0 00	60	4 00	120	8 00	180	12 00	240	16 00	300	20 00	0	0 00
1	0 04	61	4 04	121	8 04	181	12 04	241	16 04	301	20 04	1	0 04
2	0 08	62	4 08	122	8 08	182	12 08	242	16 08	302	20 08	2	0 08
3	0 12	63	4 12	123	8 12	183	12 12	243	16 12	303	20 12	3	0 12
4	0 16	64	4 16	124	8 16	184	12 16	244	16 16	304	20 16	4	0 16
5	0 20	65	4 20	125	8 20	185	12 20	245	16 20	305	20 20	5	0 20
6	0 24	66	4 24	126	8 24	186	12 24	246	16 24	306	20 24	6	0 24
7	0 28	67	4 28	127	8 28	187	12 28	247	16 28	307	20 28	7	0 28
8	0 32	68	4 32	128	8 32	188	12 32	248	16 32	308	20 32	8	0 32
9	0 36	69	4 36	129	8 36	189	12 36	249	16 36	309	20 36	9	0 36
10	0 40	70	4 40	130	8 40	190	12 40	250	16 40	310	20 40	10	0 40
11	0 44	71	4 44	131	8 44	191	12 44	251	16 44	311	20 44	11	0 44
12	0 48	72	4 48	132	8 48	192	12 48	252	16 48	312	20 48	12	0 48
13	0 52	73	4 52	133	8 52	193	12 52	253	16 52	313	20 52	13	0 52
14	0 56	74	4 56	134	8 56	194	12 56	254	16 56	314	20 56	14	0 56
15	1 00	75	5 00	135	9 00	195	13 00	255	17 00	315	21 00	15	1 00
16	1 04	76	5 04	136	9 04	196	13 04	256	17 04	316	21 04	16	1 04
17	1 08	77	5 08	137	9 08	197	13 08	257	17 08	317	21 08	17	1 08
18	1 12	78	5 12	138	9 12	198	13 12	258	17 12	318	21 12	18	1 12
19	1 16	79	5 16	139	9 16	199	13 16	259	17 16	319	21 16	19	1 16
20	1 20	80	5 20	140	9 20	200	13 20	260	17 20	320	21 20	20	1 20
21	1 24	81	5 24	141	9 24	201	13 24	261	17 24	321	21 24	21	1 24
22	1 28	82	5 28	142	9 28	202	13 28	262	17 28	322	21 28	22	1 28
23	1 32	83	5 32	143	9 32	203	13 32	263	17 32	323	21 32	23	1 32
24	1 36	84	5 36	144	9 36	204	13 36	264	17 36	324	21 36	24	1 36
25	1 40	85	5 40	145	9 40	205	13 40	265	17 40	325	21 40	25	1 40
26	1 44	86	5 44	146	9 44	206	13 44	266	17 44	326	21 44	26	1 44
27	1 48	87	5 48	147	9 48	207	13 48	267	17 48	327	21 48	27	1 48
28	1 52	88	5 52	148	9 52	208	13 52	268	17 52	328	21 52	28	1 52
29	1 56	89	5 56	149	9 56	209	13 56	269	17 56	329	21 56	29	1 56
30	2 00	90	6 00	150	10 00	210	14 00	270	18 00	330	22 00	30	2 00
31	2 04	91	6 04	151	10 04	211	14 04	271	18 04	331	22 04	31	2 04
32	2 08	92	6 08	152	10 08	212	14 08	272	18 08	332	22 08	32	2 08
33	2 12	93	6 12	153	10 12	213	14 12	273	18 12	333	22 12	33	2 12
34	2 16	94	6 16	154	10 16	214	14 16	274	18 16	334	22 16	34	2 16
35	2 20	95	6 20	155	10 20	215	14 20	275	18 20	335	22 20	35	2 20
36	2 24	96	6 24	156	10 24	216	14 24	276	18 24	336	22 24	36	2 24
37	2 28	97	6 28	157	10 28	217	14 28	277	18 28	337	22 28	37	2 28
38	2 32	98	6 32	158	10 32	218	14 32	278	18 32	338	22 32	38	2 32
39	2 36	99	6 36	159	10 36	219	14 36	279	18 36	339	22 36	39	2 36
40	2 40	100	6 40	160	10 40	220	14 40	280	18 40	340	22 40	40	2 40
41	2 44	101	6 44	161	10 44	221	14 44	281	18 44	341	22 44	41	2 44
42	2 48	102	6 48	162	10 48	222	14 48	282	18 48	342	22 48	42	2 48
43	2 52	103	6 52	163	10 52	223	14 52	283	18 52	343	22 52	43	2 52
44	2 56	104	6 56	164	10 56	224	14 56	284	18 56	344	22 56	44	2 56
45	3 00	105	7 00	165	11 00	225	15 00	285	19 00	345	23 00	45	3 00
46	3 04	106	7 04	166	11 04	226	15 04	286	19 04	346	23 04	46	3 04
47	3 08	107	7 08	167	11 08	227	15 08	287	19 08	347	23 08	47	3 08
48	3 12	108	7 12	168	11 12	228	15 12	288	19 12	348	23 12	48	3 12
49	3 16	109	7 16	169	11 16	229	15 16	289	19 16	349	23 16	49	3 16
50	3 20	110	7 20	170	11 20	230	15 20	290	19 20	350	23 20	50	3 20
51	3 24	111	7 24	171	11 24	231	15 24	291	19 24	351	23 24	51	3 24
52	3 28	112	7 28	172	11 28	232	15 28	292	19 28	352	23 28	52	3 28
53	3 32	113	7 32	173	11 32	233	15 32	293	19 32	353	23 32	53	3 32
54	3 36	114	7 36	174	11 36	234	15 36	294	19 36	354	23 36	54	3 36
55	3 40	115	7 40	175	11 40	235	15 40	295	19 40	355	23 40	55	3 40
56	3 44	116	7 44	176	11 44	236	15 44	296	19 44	356	23 44	56	3 44
57	3 48	117	7 48	177	11 48	237	15 48	297	19 48	357	23 48	57	3 48
58	3 52	118	7 52	178	11 52	238	15 52	298	19 52	358	23 52	58	3 52
59	3 56	119	7 56	179	11 56	239	15 56	299	19 56	359	23 56	59	3 56

The above table is for converting expressions in arc to their equivalent in time; its main use in this Almanac is for the conversion of longitude for application to L.M.T. (*added* if *west*, *subtracted* if *east*) to give G.M.T., or vice versa, particularly in the case of sunrise, sunset, etc.

Figure 5. Conversion of Arc To Time Table

FRAME 5

The sunset, and the morning and evening civil twilight tables are read just like the sunrise table. Remember, these times are the Local Mean Time (LMT) for the event, and can be converted to either Local Standard Time or Universal Time (GMT) by using the Conversion of Arc to Time table (Figure 5) of the Almanac. Notice that the conversion factor in the Arc to Time Table is simply 1° of longitude equals 4 minutes time. The first six columns of the table are the hours and minutes conversion, while the last column is the minutes and seconds conversion. For example, (using Figure 5) we will find the time difference corresponding to a longitude difference of 147° 37'. located 147° in the third column. you will find that 147° equals 9 hr 48 min and the 37' = 2 min 28 sec. add them together:

$$\begin{array}{r} 9 \text{ hr } 48 \text{ min} \\ + \quad 2 \text{ min } 28 \text{ sec} \\ \hline 9 \text{ hr } 50 \text{ min } 28 \text{ sec} \end{array}$$

In computing these times, you can round off to the nearest minute. thus, the time difference corresponding to a longitude difference of 147° 37' is 9 hr. 50 min.

Find the time difference corresponding to the following longitude differences. Round off the time to the nearest minute.

A. 76° 17' _____

B. 14° 55' _____

C. 122° 39' _____

D. 120° 16' _____

****

ANSWER:

A. 5 hr 05 min

B. 1 hr 00 min

C. 8 hr 11 min

D. 8 hr 01 min

FRAME 6

Using the Conversion of Arc To Time Table to convert LMT to GMT is fairly simple, since you are simply converting from your longitude position to the 0° Meridian. First, convert your longitude to time; then, add this conversion to LMT if your longitude is west, or subtract it from LMT if your longitude is east.

For example, here is the conversion of 0630 LMT to GMT for Langley AFB, Va, which is located at 76° 21' W.

```
 76°     = 5 hr 04 min
+ 21'=       01 min 24 sec
-------------------------
      5 hr 05 min 24 sec  = 5 hr 05min

      6 hr 30 min LMT
    + 5 hr 05 min (added; longitude is west)
    -----------------
     11 hr 35 min = 1135 GMT
```

Convert 0630 LMT on 18 May to GMT for the following stations:

A. Fulda, Germany 9° 41' E. _____

B. Osan, Korea 127° 02' E. _____

C. Brasilia, Brazil 47° 56' W. _____

D. Amberley, Australia 152° 43' E. _____

****

ANSWER:

A. 0552 GMT, 18 May

B. 2202 GMT, 17 May

C. 0942 GMT, 18 May

D. 2019 GMT, 17 May

Frame 7

The easiest way to find LST using strictly the Air Almanac and nothing else is to simply find GMT, as you did in Frame 6, and apply the correction to standard time which is indicated in pages A20-A23 of the Air Almanac. NOTE: Standard Time corrections are also located in the Flight Information Publication (FLIP) pertaining to your Area of interest. The Standard Time zones are based on specific Standard Meridians which are normally spaced at 15° of longitude, either east or west, beginning with the Prime Meridian (0°); however, either geographical considerations or local law can be used to adjust Standard Time. Because the LST for your location must be figured using The Standard Meridian for your time zone, which is not necessarily the one closest to it, you must insure that the proper correction is applied. e.g. In eastern and western Kentucky there are 2 different time zones; Newfoundland has a Standard Time correction of +3 hrs 30 Minutes etc.

If you *do know* the Standard Meridian that is used for your time zone then you simply apply the correction as determined from the Arc to Time Table to the Local Mean Time listed in the Sunrise/set tables. Add the correction if you are west of the Standard Meridian and subtract the correction if you are east. This correction will normally be less than 1 hour, remember, because Standard Meridians are normally 15° apart, and 1° of longitude = 4 minutes time. (See the map on page 49)

Let's use Langley AFB, VA as an example of this last case. Langley, which is located at 37° 05' N., 76° 21' W. is in the Eastern Standard Time Zone which uses 75° West longitude as it's Standard Meridian. The LMT for sunrise on the 18th of March is 0608 LMT. What time does sunrise (LST) occur at Langley? Langley AFB, VA is located 1° 21' West of the Standard Meridian and this equates to a correction of 5 minutes (1° 21' = 5 min 24 sec which rounds off to 5 min). The correction added to the published LMT, indicates a sunrise time at Langley AFB on 18 March of 0613 LST.

Find time of sunrise (LST) for the following stations using a time of 0630 LMT:

	Standard Meridian	
A. Fulda, Germany (9° 41' E.)	15° E.	_____
B. Osan, Korea (127° 02' E.)	135° E.	_____
C. Brasilia, Brazil (47° 56' W.)	45° W.	_____
D. Amberley, Australia (152° 43' E.)	150° E.	_____

****

ANSWER:

A. 0651 LST

B. 0702 LST

C. 0642 LST

D. 0619 LST

FRAME 8

Some locations use Daylight Savings Time (LDT). For an indication of which countries use LDT see the Standard Time tables pp. A20-23 or the applicable Flight information Publication for your area of interest. To convert to Daylight Savings Time (LDT) you just add 1 hour to the LST.

Using the following Figure (Figure 6) and the Conversion of Arc to Time Table (Figure 5), find the LDT of sunset on 11 September for the following stations:

		Standard Meridian	
A. Fulda, FRG.	(50° 33' N. 9° 41' E.)	15° E.	_____
B. Langley AFB, Va	(37° 05' N. 76° 21' W.)	75° W.	_____
C. Brasilia, Bra.	(15° 51' S. 47° 56' W.)	45° W.	_____
D. Amberley, Aus.	(27° 39' S. 152° 43' E.)	150° E.	_____

SUNSET

Lat.	August						September										Oct.
	15	18	21	24	27	30	2	5	8	11	14	17	20	23	26	29	2
	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m
N 72	21 45	21 24	21 04	20 46	20 28	20 11	19 54	19 38	19 22	19 06	18 50	18 34	18 19	18 03	17 48	17 33	17 17
70	21 13	20 57	20 41	25	20 10	19 56	41	27	12	18 58	44	30	16	02	49	35	21
68	20 56	36	23	20 10	19 56	44	31	18	19 05	52	39	27	14	02	49	36	24
66	42	20	20 09	19 57	45	34	22	10	18 59	47	35	24	12	01	49	38	26
64	28	20 07	19 57	46	36	25	15	19 04	54	43	32	22	11	00	50	39	29
62	20 06	19 56	47	37	28	18	09	18 59	49	39	29	19	10	18 00	50	40	30
N 60	19 55	19 47	19 38	19 29	19 21	19 12	19 03	18 54	18 45	18 36	18 27	18 17	18 08	17 59	17 50	17 41	17 32
58	46	39	31	23	15	06	18 58	50	41	33	24	16	07	59	50	42	34
56	39	31	24	17	09	19 02	54	46	38	30	22	14	06	58	51	43	35
54	32	25	18	11	04	18 57	50	43	35	28	21	13	06	58	51	43	36
52	25	19	13	07	19 00	53	47	40	33	26	19	12	05	58	51	44	37
N 50	19 20	19 14	19 08	19 02	18 56	18 50	18 44	18 37	18 31	18 24	18 18	18 11	18 04	17 58	17 51	17 45	17 38
45	19 08	19 03	18 58	18 53	48	42	37	31	26	20	14	09	03	57	52	46	40
40	18 58	18 54	50	45	41	36	31	26	22	17	12	07	02	57	52	47	42
35	49	46	42	38	34	31	26	22	18	14	10	05	01	57	52	48	44
30	42	39	36	33	29	26	22	19	15	11	08	04	18 00	56	53	49	45
N 20	18 29	18 27	18 25	18 23	18 20	18 18	18 15	18 13	18 10	18 07	18 04	18 02	17 59	17 56	17 53	17 51	17 48
N 10	18	17	15	14	12	11	09	07	05	03	18 02	18 00	58	56	54	52	50
0	18 08	18 07	18 07	18 06	18 05	18 04	18 03	18 02	18 01	18 00	17 59	17 58	57	56	55	54	53
S 10	17 58	17 58	17 58	17 58	17 58	17 58	17 58	17 57	17 57	17 57	57	56	56	56	56	56	55
20	47	48	49	50	50	51	52	52	53	54	54	55	55	56	57	17 57	17 58
S 30	17 35	17 37	17 39	17 40	17 42	17 43	17 45	17 47	17 48	17 50	17 51	17 53	17 55	17 56	17 58	18 00	18 01
35	28	30	33	35	37	39	41	44	46	48	50	52	54	57	17 59	01	04
40	20	23	26	29	32	34	37	40	43	46	48	51	54	57	18 00	03	06
45	11	15	18	22	25	29	32	36	39	43	46	50	54	57	01	05	08
50	17 00	05	09	13	18	22	27	31	35	40	44	49	53	58	02	07	12
S 52	16 55	17 00	17 05	17 09	17 14	17 19	17 24	17 29	17 34	17 38	17 43	17 48	17 53	17 58	18 03	18 08	18 13
54	50	16 55	17 00	05	11	16	21	26	32	37	42	47	53	58	04	09	15
56	43	49	16 55	17 01	06	12	18	24	29	35	41	47	53	58	04	10	16
58	37	43	49	16 55	17 02	08	14	21	27	33	40	46	52	59	05	12	18
S 60	16 29	16 36	16 42	16 49	16 56	17 03	17 10	17 17	17 24	17 31	17 38	17 45	17 52	17 59	18 06	18 13	18 21

Figure 6. Sunset Table.

ANSWER:

A. 1946 LDT

B. 1920 LDT

C. 1807 LST — Why not LDT? Because it's not summer in the

D. 1740 LST — southern hemisphere! Gotcha!!!!

PROGRESS CHECK

FRAME 9:

Using the extracts from the four sun-event tables provided below and the Conversion of Arc to Time table in figure 5, find the Local Standard Times for the start of morning civil twilight, sunrise, sunset, and the end of civil twilight on 1 January for the following stations:

A. Langley AFB, Va (37° 05' N. 76° 21' W.)

B. Amberley, Aus. (27° 39' S. 152° 43' E.)

	AM Twilight	Sunrise	Sunset	PM Twilight
A.				
B.				

Lat.	Dec. 30	Dec. 2
	h m	h m
N 72	10 48	10 40
70	09 52	09 48
68	09 18	09 10
66	08 54	08 52
64	35	34
62	19	18
N 60	08 06	08 05
58	07 54	07 54
56	44	44
54	36	35
52	28	28
N 50	07 20	07 20
45	07 04	07 05
40	06 51	06 52
35	40	40
30	29	30
N 20	06 10	06 11
N 10	05 53	05 54
0	30	38
S 10	05 19	20
20	04 58	05 00
S 30	04 33	04 36
35	18	21
40	04 00	04 03
45	03 38	03 41
50	03 09	03 12
S 52	02 54	02 58
54	37	40
56	02 15	02 19
58	01 46	01 51
S 60	01 00	01 08

Lat.	Dec. 30	Dec. 2
	h m	h m
N 72	—	—
70	—	—
68	—	—
66	10 31	10 26
64	09 51	09 49
62	24	22
N 60	09 03	09 02
58	08 46	08 45
56	32	31
54	19	19
52	08 08	08 08
N 50	07 58	07 58
45	38	38
40	22	22
35	07 08	07 08
30	06 55	06 56
N 20	06 34	06 35
N 10	06 16	17
0	05 59	06 00
S 10	42	05 43
20	23	25
S 30	05 01	05 03
35	04 48	04 50
40	33	36
45	04 15	04 18
50	03 53	03 56
S 52	03 43	03 46
54	30	34
56	16	20
58	03 00	03 04
S 60	02 40	02 44

Lat.	Dec. 30	Dec. 2
	h m	h m
N 72	—	—
70	—	—
68	—	—
66	13 34	13 42
64	14 14	14 20
62	14 41	14 46
N 60	15 02	15 06
58	20	23
56	34	37
54	46	15 50
52	15 57	16 00
N 50	16 07	16 10
45	27	30
40	44	16 48
35	16 58	17 00
30	17 10	12
N 20	17 31	17 33
N 10	17 49	17 51
0	18 06	18 08
S 10	24	25
20	18 42	18 43
S 30	19 04	19 05
35	17	18
40	32	32
45	19 50	19 50
50	20 12	20 12
S 52	20 22	20 22
54	34	34
56	20 48	20 47
58	21 05	21 03
S 60	21 25	21 23

Lat.	Dec. 30	Dec. 2
	h m	h m
N 72	13 18	13 20
70	14 13	14 20
68	14 47	14 52
66	15 11	15 16
64	30	35
62	46	15 50
N 60	15 59	16 03
58	16 11	14
56	21	24
54	30	33
52	38	41
N 50	16 45	16 48
45	17 01	17 04
40	15	17
35	20	28
30	36	38
N 20	17 55	17 57
N 10	18 12	18 14
0	29	30
S 10	18 47	18 48
20	19 07	19 08
S 30	19 32	19 32
35	19 47	19 47
40	20 05	20 05
45	20 27	27
50	50	20 55
S 52	21 11	21 10
54	28	27
56	21 50	21 48
58	22 18	22 15
S 60	23 03	22 57

Figure 7. Sun Events Tables

ANSWER:

A. 0650,0719,1659,1728

B. 0430,0457,1849,1915

(Answers within one minute of these can be considered correct because of the interpolation involved.)

ONE FINAL NOTE: Nautical and Astronomical Twilight times are not provided in the Air Almanac, but can be estimated by using the time difference between sunrise and start of civil twilight, or sunset and end of civil twilight. Add the difference to end of Civil Twilight to get the end of nautical twilight; add the difference again to get end of astronomical twilight. For corresponding start of twilight times, subtract the difference from starts of civil twilight etc.

So far, you have learned how to find times of sunrise/set, and the twilights between the latitudes of 72° North and 60° South. Although the Air Almanac does not cover the area south of 60° South latitude, it does cover the area north of 72° North. The next few frames will explain these graphs.

NO RESPONSE NECESSARY

FRAME 10:

An example of a Semiduration of Sunlight Graph is shown below.

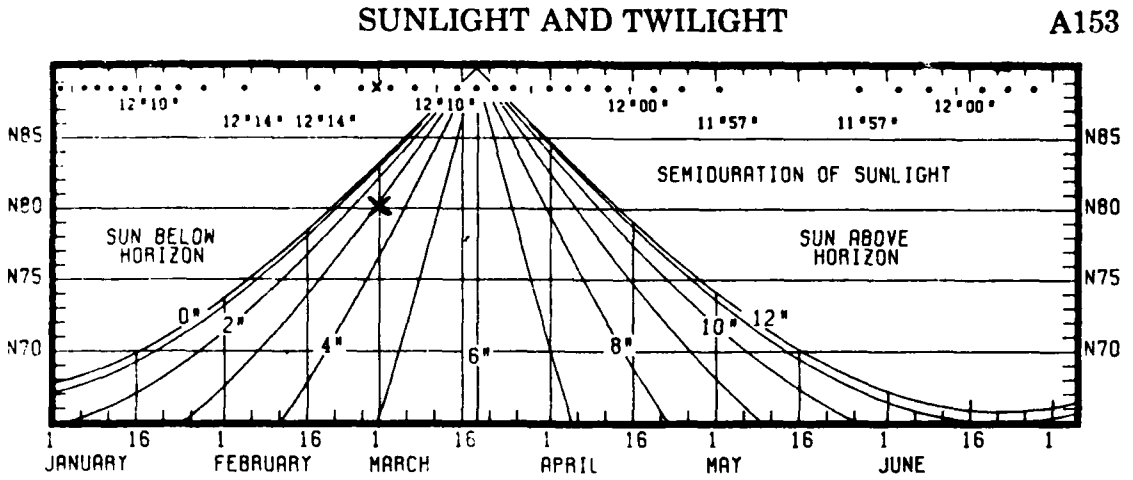


Figure 8. Semiduration of Sunlight

The graph covers a six-month period; the months are indicated across the bottom. Every fifth day there are tick marks; they are depicted along the top and bottom of each chart. The sides of the graph indicate latitudes from 65° North to 90° North. Across the top you also see time in hours and minutes. e.g. 12H 14m ....etc. These times are the times of meridian passage which can be read to the nearest minute for each day. Meridian passage is the time that the sun passes your longitude; i.e. the time of apparent noon during each 24-hour period. The skewed lines on the graph are the semiduration lines. They show the number of hours of sunlight that will occur before and after the meridian passage--hence the term "semiduration". "Sun below horizon" and "Sun above horizon" are self-explanatory. In the regions of the graph that you find difficult to interpret, the phenomena themselves are generally speaking, uncertain.

FRAME 10 (contd)

Here's an example of how to read the graph to find the sunrise/set times on 1 March at 80° North (using figure 8): first, follow the "1 March" line to the top of meridian passage. An "x" has been placed there, between 12h 14m and 12h 10 m, or approximately 12h 12m. Thus, the meridian passage time on 1 March for any meridian is 12h 12m LMT. Next proceed along the line to your latitude of interest (80° N.). An "x" has also been placed at that point. This point lies approximately on the skewed line labelled "3h." Therefore, the semiduration of sunlight on 1 March at 80° North latitude is 3 hours. With 3 hours sunlight before and after the meridian passage time you can now compute the sunrise to be 0912 LMT (12 - 3h = 0912) and the sunset to be 1512 LMT (12h 12m + 3h = 1512) Now it's your turn! Use figure 8 and find local mean times of sunrise/set for the following dates and latitudes. (A clear straight edge will be useful here.)

		Sunrise	Sunset
A. 16 April,	80° N.	_____	_____
B. 10 February,	70° N.	_____	_____
C. 15 March,	78° N.	_____	_____
D. 1 April,	73° N.	_____	_____

****

ANSWER:

A. Sun continuously above horizon.

B. 0854 LMT 1534 LMT

C. 0639 LMT 1739 LMT

D. 0449 LMT 1919 LMT

FRAME 11

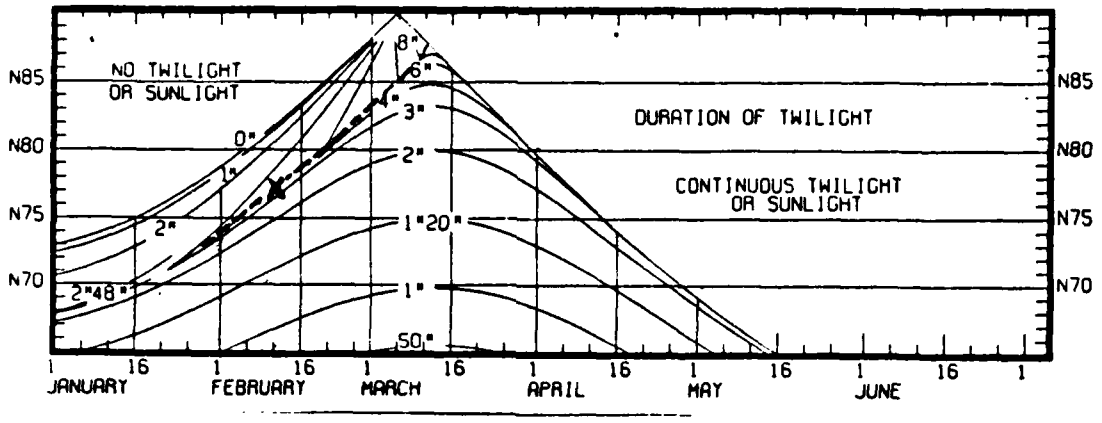


Figure 9. Duration of Twilight Graph

The Duration of Twilight graph (Figure 9) is similar to the Semiduration of Sunlight graph; but notice that the skewed hour lines are not smoothly curved as they are on the sunlight graph. They are kinked in places. These kinks, if superimposed onto the corresponding sunlight graph, would fall on the "0h" line, and along this line the sunrise may or may not occur. We have drawn a dashed line in the example which enables us to define the four areas in the chart as follows:

Area A - No Twilight or sunlight. In this area the sun never gets within 6° of the horizon.

Area B - This is the area where the sun is continuously below the horizon but does get near enough (within 6°) to the horizon during a portion of the day that there is twilight. The value determined in this region of the graph is actually the interval between the beginning of twilight and the time of meridian passage.

Area C - This value when applied to the time of sunrise (-) or sunset (+) gives you the amount of available twilight

Area D - Continuous Twilight or Sunlight - self-explanatory.

FRAME 11 (contd)

Let's work an example to show just how this graph works (see figure 8) on a worst case scenario. We want to find out the amount of twilight available on 11 February at 77° North (Point "x"). As you can see it sits in the heart of the transition zone between sunrise and no sunrise. The first thing we do is draw a dotted line connecting the kinks in the hour lines. Point "x" is located between the "3h" lines, so we must interpolate between the 3h and 4h lines to get a usable value to work with. It is located about 2/3 of the way (2/3 of 60 min = 40 minutes), so the correct value of twilight is 3h 40 min. The sun may or may not rise completely above the horizon on this date at this position. A good light forecast for this date would be 7 hrs 20 minutes of twilight, with the possibility of the sun actually being visible for a few minutes around the time of meridian passage.

Now, you work a few examples. Find the total duration of twilight (using figure 9) for the following dates:

A. 16 January, 78° N. _____

B. 1 February, 73° N. _____

C. 31 March , 80° N. _____

D. 16 February, 80° N. _____

ANSWER:

A. No Twilight or sunlight.

B. 6 hr 00 min.

C. Continuous twilight or sunlight.

D. 6 hr 40 min.

FRAME 12

The Duration of Twilight (Figure 11) graph is read in conjunction with the Semiduration of Sunlight graph (Figure 10). Notice that the twilight graph does not have the times for meridian passage on it. However, since the twilight graph is always placed directly underneath the sunlight graph in the Air Almanac, the meridian passage time can be obtained with a straightedge, if necessary.

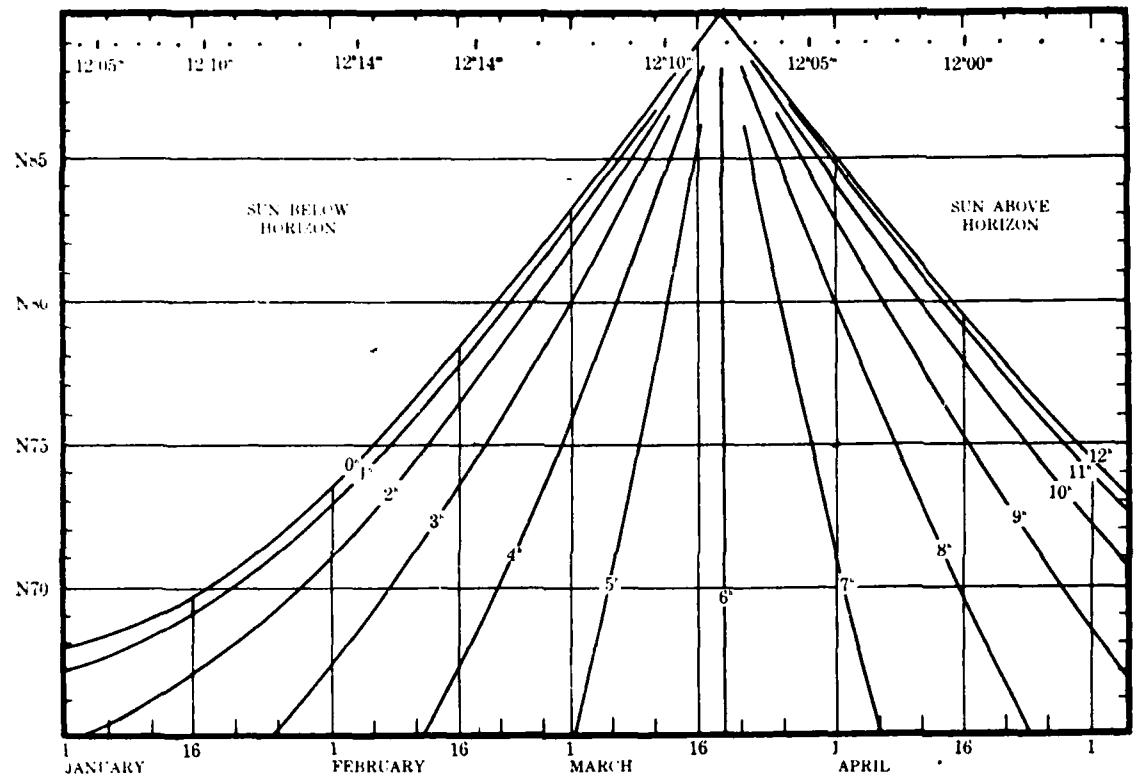


Figure 10. Semiduration of Sunlight

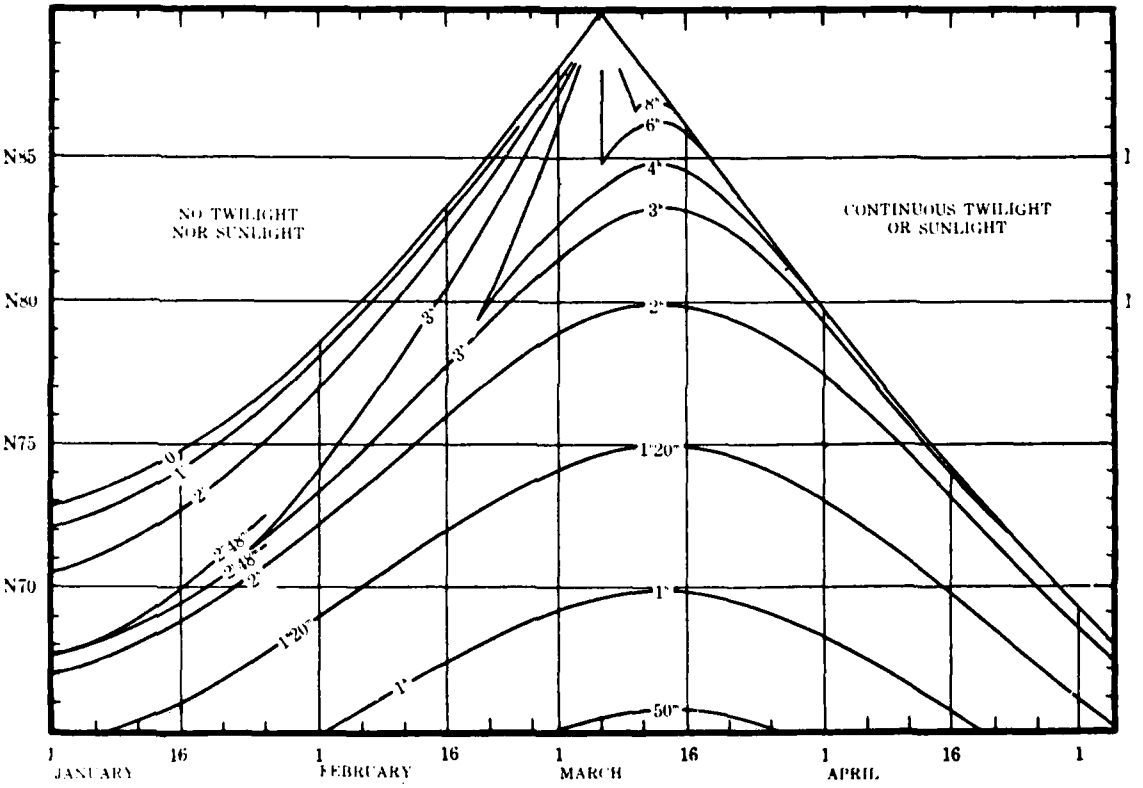


Figure 11. Duration of Twilight

FRAME 12 (contd)

Let's recap the steps for finding the times of sunrise/set, and twilight times in the 65° to 90° North latitude region.

1. Find the time of meridian passage.
2. Find the Semiduration of Sunlight.
3. Apply the value to the meridian passage time for sunrise (subtract) and sunset (add).
4. Find the duration of twilight.
5. Apply the value to the sunrise time (subtract) for begin time of morning twilight and to the sunset (add) to obtain the end of evening twilight.
6. Remember, even if there is no sunrise or sunset there can still be twilight. Subtract the value from the meridian passage time for beginning time; add the value to the meridian time to compute the end time of twilight.

Now let's find the local mean times (using Figures 9 and 10) for all of the events listed below:

	BEGIN TWI	SUNRISE	SUNSET	END TWI
A. 18 February, 75° N.	_____	_____	_____	_____
B. 16 April , 78° N.	_____	_____	_____	_____
C. 1 March , 84° N.	_____	_____	_____	_____
D. 1 April , 75° N.	_____	_____	_____	_____

ANSWER:

A. 0744, 0924, 1504, 1644
B. Continuous, 0200, 2200, Continuous
C. 0722, None, None, 1702
D. 0304, 0444, 1924, 2104

(Twilight times within 15 minutes of our answers may be considered as correct)

FRAME 13

To compute the sun's azimuth and elevation at a specific time and place, you must use the daily pages and Interpolation of GHA Table in the Air Almanac.

You will need a hand-held calculator; there are numerous programs available for both the TI-59, and HP 41 calculators. Programs are also being developed for microcomputers. See AWS TC 8X/001 for a listing of available programs. They are simple to use; just fill in the values from the Air Almanac, as directed.

NOTE: The time of sunrise/set is given as the time the observer on earth would first see the upper edge of the sun along the horizon. However, solar altitude is determined by the position of the sun's center not it's edge. Consequently, the time that the solar altitude equals 0° may not exactly match the time of sunrise/set.

NO RESPONSE NECESSARY

FRAME 14

You should now be able to calculate sunrise/set, and twilight times for any point North of 60° S. The next few frames will teach you how to find moonrise and moonset times for the same area. Their organization in the Air Almanac is the same as for sun times; there are tables for latitudes between 72° N. and 60° S., and graphs for latitudes between 65° and 90° N. Before discussing how to read these tables and graphs, let's look at some of the reasons that make them necessary.

NO RESPONSE NECESSARY

FRAME 15

The moon revolves around the earth once every 28 days or so. The phases of the moon are caused by its position in its orbit. Using figure 12 you can see how the moon is viewed from earth, by looking at the outer figures at each position. From space the moon can be

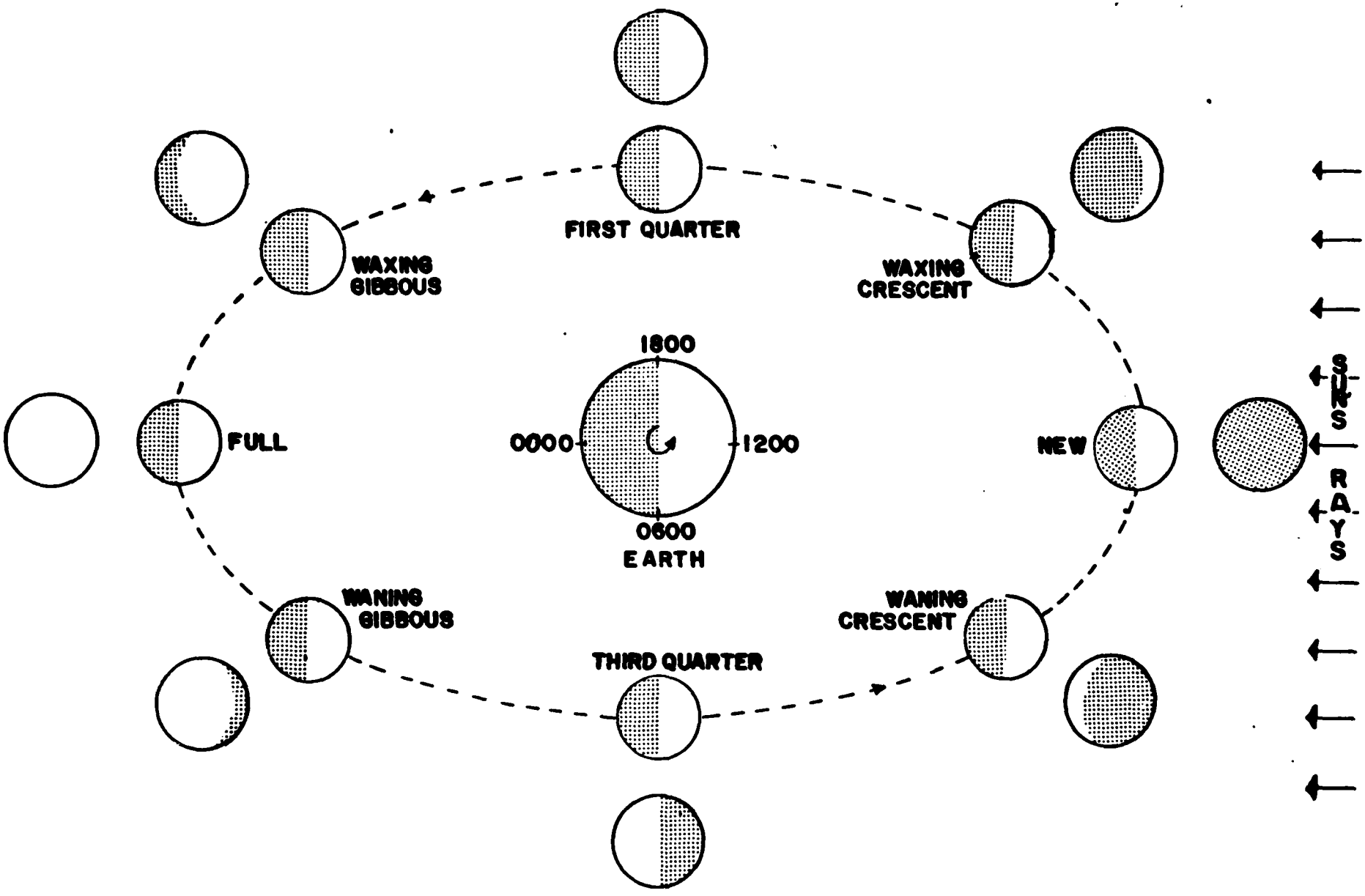


Figure 12. ILLUSTRATION OF LUNAR ORBIT AND PHASES

FRAME 15 (contd)

seen as half-illuminated at all times (the inner figures).

The 24 hour clock face around the earth illustrates to you how you can obtain a rough estimate of the times of moonrise and moonset by the phase of the moon. Look at the full moon portion of the diagram, which is adjacent to 0000 time on the clock face. The full moon crosses the meridian around midnight. Imagine that you are at a point on the right edge of the clock-face earth. As this point turns counter-clockwise (direction of the arrow), the full moon becomes visible as you approach the 1800 position. Moonrise occurs at about 1800 for a full moon. Continuing around the clock face, the moon would recede from your view at about 0600. Moonset occurs around 0600 for a full moon.

In other words, the moon is 'full' because it is located on the side of the earth opposite the sun. We tell time on earth by our position in the daily rotation of the earth with respect to the sun. A full moon can only be seen from earth from about 1800 to 0600 because of the mechanics of the situation.

EXCEPTION: In extremely high latitudes, the mechanics get more complicated due to the axis tilt and other irregularities that will be dealt with in succeeding frames.

The other phases of the moon are only visible between certain hours for the same reasons.

Using Figure 12, state the approximate times of moonrise and moonset for:

	MOONRISE	MOONSET
A. Third Quarter Moon	_____	_____
B. Full Moon	_____	_____
C. First Quarter Moon	_____	_____

****

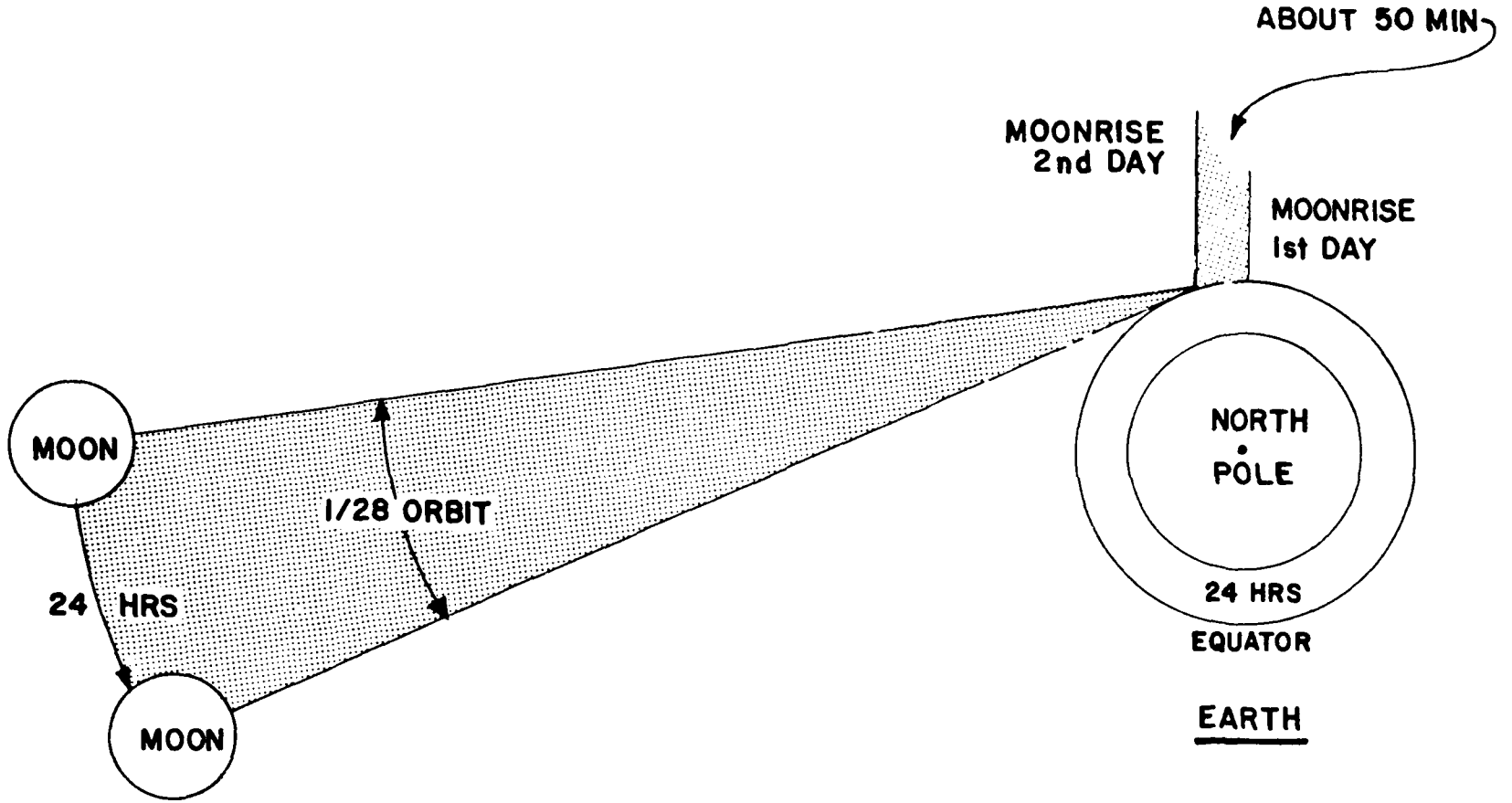


Figure 13. ILLUSTRATION OF HOW CONSTANT ORBITAL SPEED AND ZERO ORBITAL ANGLE WOULD AFFECT MOONRISE TIMES

ANSWER:

A. 0000 1200

B 1800 0600

C. 1200 0000

FRAME 16

Two factors cause moonrise and moonset times to change from day to day. They are the moon's orbital speed and its orbital angle. Let's see if we can explain that more fully. Assume that both the moon's orbital speed and angle are constant. This would result from the idealized situation of the moon being in a circular orbit directly above the equator. The moon orbits the earth once every 28 days; this equates to 1/28 of its orbit being completed every 24 hours. 1/28 of 24 hours equals approximately 51 minutes. Now, with the moon making a circular orbit in the same direction that the earth turns this would mean that the moonrise/set would occur about 51 minutes later each day (See Figure 13).

The exaggerated illustration in Figure 12 looks down on the earth at the North Pole with the equator the edge of the circle. The earth is rotating clockwise and the moon is orbiting in the same direction. Therefore, each day (24 hours) when a standard meridian on earth makes a complete revolution, it must continue on for 51 more minutes for the moon to come in view. Consequently, moonrise occurs 51 minutes later each day.

Because of it's orbital speed, the moon would rise about 51 minutes later each day if the moon's orbit was:

A. Elliptical and inclined to the equator.

B. Circular, and directly above the equator.

****

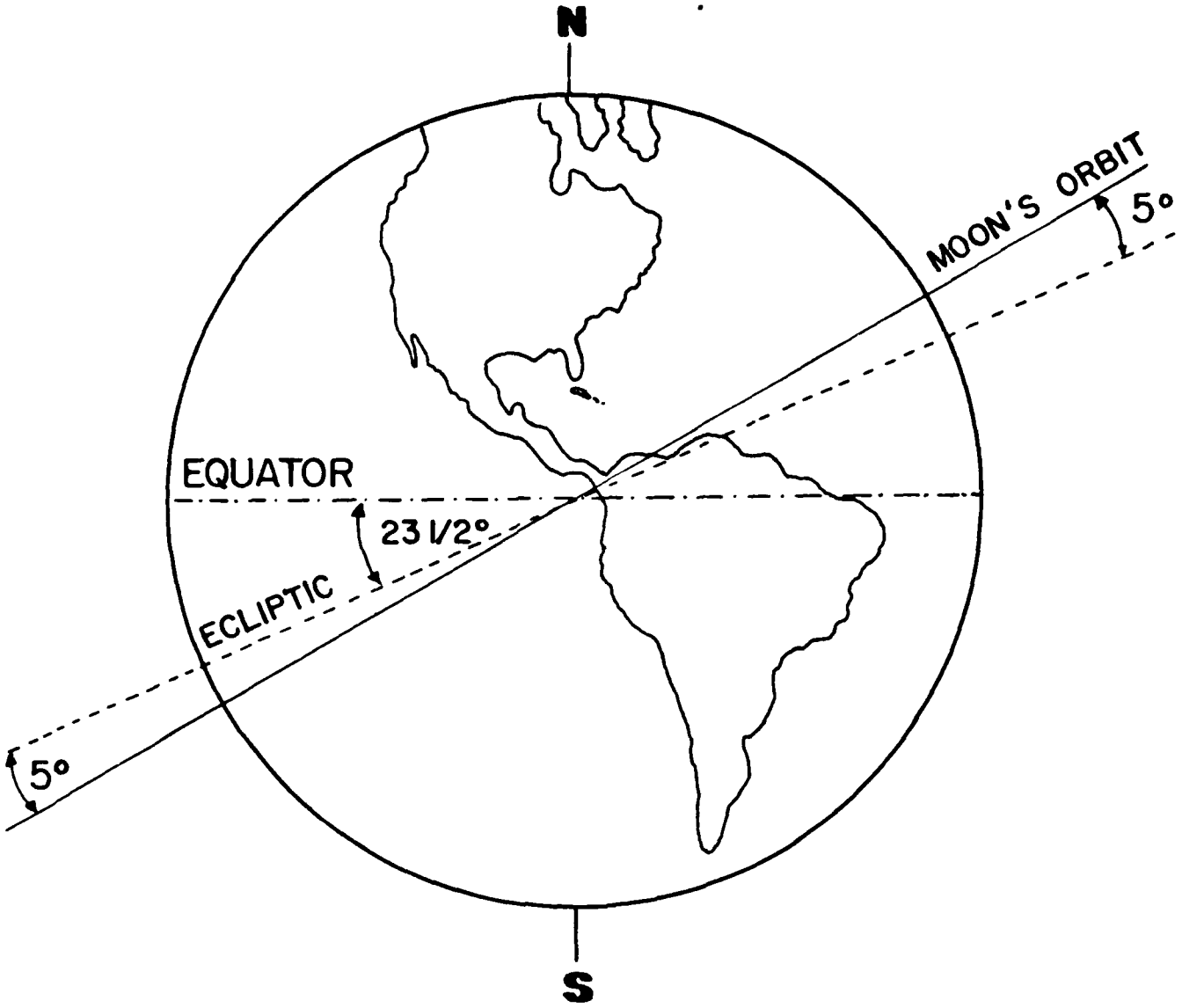


Figure 14. ECLIPTIC AND ORBITAL PATH OF MOON RELATIVE TO EQUATORIAL PLANE OF EARTH

ANSWER:

A. Circular and directly above the equator.

FRAME 17

With the moon in a circular orbit above the equator, moonrise would occur about 51 minutes later each day for all positions on the earth (except the poles). However, the moon is, in fact, neither in a circular orbit, nor does it orbit directly over the equator. What does this mean? Well, for any one position in the low and mid latitudes the moon does rise about 51 minutes later each day, but the difference along a single meridian longitude can vary more than 6 hours between 60° S. and 72° N. This is mainly because of the moon's orbital angle. Rather than orbitting directly above the, equator the moon moves both north and south of the equator during each orbit. When the moon is in the northern part of its orbit, it can be seen earlier by northern observers than by those to the south, and vice versa.

Earlier, you learned that the sun moves 23 1/2° north and south of the equator during the course of a year because of the earth's axis tilt. The apparent path of the sun across the sky is called the ecliptic. The ecliptic crosses the equator at an angle of 23 1/2°. The moon's path crosses the ecliptic at an angle of 5°. The point where they intersect moves around the ecliptic in a little more than 18 years, causing the angle at which the moon crosses the equator to vary between 18 1/2° and 28 1/2°. These apparent paths are illustrated in Figure 14.

Moonrise varies by latitude along a particular meridian of longitude mainly because of the moon's:

A. orbital speed.

B. orbital angle.

C. elliptical orbit

D. circular orbit.

****

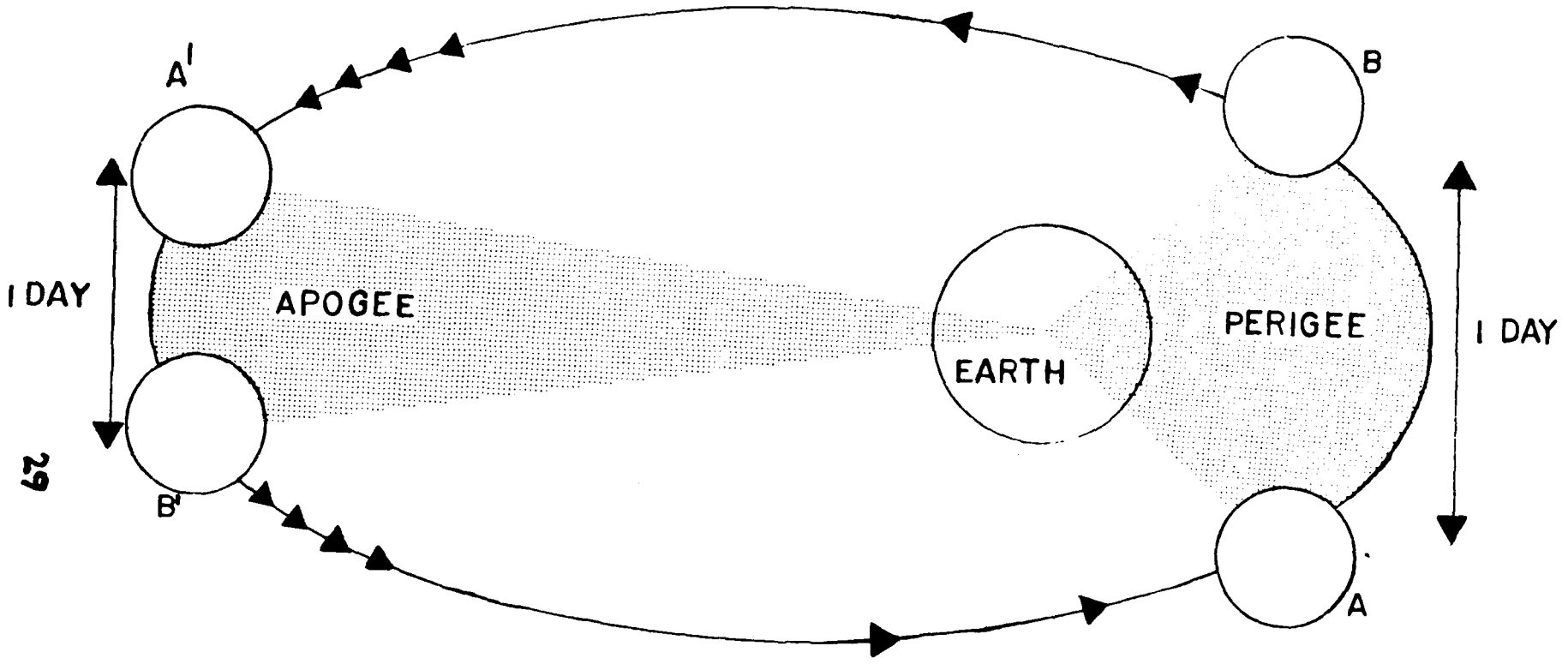


FIGURE 15. ILLUSTRATION OF NON-UNIFORM ORBITAL SPEED OF MOON

FRAME [illegible]

ANSWER:

[illegible] B

[illegible] the [illegible] circular, it is elliptical. This [illegible] earth at times (perigee) and farther away [illegible] Law of Equal Areas, which is [illegible] moves faster in its orbit when it [illegible] when it is farther away. This much [illegible] the moon's non-uniform orbital speed [illegible] its elliptical orbit. The distance from A to B represents [illegible] day at perigee, the distance from A' to B' represents one day at Apogee.

Kepler's Law states that equal orbital areas are swept out in equal amounts of time. In other words, the two triangles have equal areas but are of different shapes. The moon is moving faster from A to B than from A' to B'. Moonrise at B would be more than 50 minutes later than at A, because the earth would have to turn farther. Conversely moonrise at B' would occur less then 50 minutes later than at A', because the earth would not have to turn so far.

The moon's elliptical orbit causes it's orbital speed to be:

A. Faster at perigee than at apogee.

B. Slower at perigee than at apogee.

****

ANSWER:

A. Faster.

FRAME [illegible]

[illegible] day to day mainly because of the [illegible] and orbital ______________.

****

ANSWER:

Speed; Angle (either order)

FRAME 19

The last few frames have shown that, although you can get a rough idea of moonrise/set times by the phases of the moon, specific times can only be obtained by considerations and calculations of data which include the moon's orbital speed and orbital angle. Next we will cover calculating the moonrise set data from the Air Almanac. If certain [illegible] this data from the Almanac seems a little complicated, you should now have some appreciation for the calculations involved. NOTE: Although it requires no calculation, Fractional Illumination data is provided in the Air Almanac. See the index for the exact page number.

****NO RESPONSE NECESSARY****

FRAME 20

To find moonrise/set times between 60° S. and 72° N. from the Air Almanac, you must use three different sets of tables. They are:

a. Moonrise, Moonset data (Daily Pages).

b. Interpolation of Moonrise, Moonset for Longitude.

c. Conversion of Arc to Time Table.

The moonset and moonrise tables are found in the upper right hand corner of each daily page. They alternate, with moonset on the left page and moonrise on the right page of each opening. The next two pages (Figures 16 and 17) are excerpts of complete daily pages with the moonrise and moonset tables circled.

NO RESPONSE NECESSARY

GMT (UT)	☉ SUN GHA	Dec	ARIES GHA	VENUS -3.9 GHA	Dec	MARS 1.7 GHA	Dec	JUPITER -2.8 GHA	Dec	● MOON GHA	Dec
h m	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
00 00	183 35.4	S19 44.8	59 27.8	159 07	S24 07	213 13	S10 01	39 42	N 6 44	188 19	S22 54
10	186 05.4	44.9	61 58.2	161 37		215 43		42 12		190 43	56
20	188 35.4	45.0	64 28.6	164 06		218 13		44 43		193 08	58
30	191 05.4	45.1	66 59.0	166 36		220 44		47 13		195 32	22 59
40	193 35.3	45.2	69 29.5	169 06		223 14		49 44		197 57	23 01
50	196 05.3	45.2	71 59.9	171 36		225 44		52 14		200 21	03
01 00	198 35.3	S19 45.3	74 30.3	174 06	S24 08	228 14	S10 01	54 44	N 6 44	202 45	S23 04
10	201 05.3	45.4	77 00.7	176 36		230 44		57 15		205 10	06
20	203 35.2	45.5	79 31.1	179 05		233 14		59 45		207 34	08
30	206 05.2	45.6	82 01.5	181 35		235 45		62 16		209 58	10
40	208 35.2	45.7	84 31.9	184 05		238 15		64 46		212 23	11
50	211 05.2	45.8	87 02.3	186 35		240 45		67 17		214 47	13
02 00	213 35.1	S19 45.9	89 32.7	189 05	S24 08	243 15	S10 02	69 47	N 6 44	217 12	S23 15
10	216 05.1	46.0	92 03.2	191 35		245 45		72 18		219 36	16
20	218 35.1	46.1	94 33.6	194 04		248 15		74 48		222 00	18
30	221 05.1	46.2	97 04.0	196 34		250 45		77 19		224 25	20
40	223 35.0	46.3	99 34.4	199 04		253 16		79 49		226 49	22
50	226 05.0	46.4	102 04.8	201 34		255 46		82 19		229 13	23
03 00	228 35.0	S19 46.5	104 35.2	204 04	S24 08	258 16	S10 02	84 50	N 6 44	231 38	S23 25
10	231 05.0	46.6	107 05.6	206 34		260 46		87 20		234 02	27
20	233 34.9	46.7	109 36.0	209 04		263 16		89 51		236 26	28
30	236 04.9	46.7	112 06.4	211 33		265 46		92 21		238 50	30
40	238 34.9	46.8	114 36.8	214 03		268 16		94 52		241 15	32
50	241 04.9	46.9	117 07.3	216 33		270 47		97 22		243 39	33
04 00	243 34.8	S19 47.0	119 37.7	219 03	S24 09	273 17	S10 03	99 53	N 6 44	246 03	S23 35
10	246 04.8	47.1	122 08.1	221 33		275 47		102 23		248 28	37
20	248 34.8	47.2	124 38.5	224 03		278 17		104 53		250 52	38
30	251 04.8	47.3	127 08.9	226 33		280 47		107 24		253 16	40
40	253 34.7	47.4	129 39.3	229 02		283 17		109 54		255 41	42
50	256 04.7	47.5	132 09.7	231 32		285 48		112 25		258 05	43
05 00	258 34.7	S19 47.6	134 40.1	234 02	S24 09	288 18	S10 04	114 55	N 6 44	260 29	S23 45
10	261 04.7	47.7	137 10.5	236 32		290 48		117 26		262 53	46
20	263 34.6	47.8	139 41.0	239 02		293 18		119 56		265 18	48
30	266 04.6	47.9	142 11.4	241 32		295 48		122 26		267 42	50
40	268 34.6	48.0	144 41.8	244 01		298 18		124 57		270 06	51
50	271 04.5	48.1	147 12.2	246 31		300 49		127 27		272 31	53
06 00	273 34.5	S19 48.1	149 42.6	249 01	S24 09	303 19	S10 04	129 58	N 6 44	274 55	S23 55
10	276 04.5	48.2	152 13.0	251 31		305 49		132 28		277 19	56
20	278 34.5	48.3	154 43.4	254 01		308 19		134 59		279 43	58
30	281 04.4	48.4	157 13.8	256 31		310 49		137 29		282 08	23 59
40	283 34.4	48.5	159 44.2	259 00		313 19		140 00		284 32	24 01
50	286 04.4	48.6	162 14.7	261 30		315 49		142 30		286 56	03
07 00	288 34.4	S19 48.7	164 45.1	264 00	S24 09	318 20	S10 05	145 00	N 6 43	289 20	S24 04
10	291 04.3	48.8	167 15.5	266 30		320 50		147 31		291 45	06
20	293 34.3	48.9	169 45.9	269 00		323 20		150 01		294 09	07
30	296 04.3	49.0	172 16.3	271 30		325 50		152 32		296 33	09
40	298 34.3	49.1	174 46.7	274 00		328 20		155 02		298 57	10
50	301 04.2	49.2	177 17.1	276 29		330 50		157 33		301 22	12
08 00	303 34.2	S19 49.3	179 47.5	278 59	S24 10	333 20	S10 06	160 03	N 6 43	303 46	S24 14
10	306 04.2	49.4	182 17.9	281 29		335 51		162 34		306 10	15
20	308 34.2	49.5	184 48.3	283 59		338 21		165 04		308 34	17
30	311 04.1	49.5	187 18.8	286 29		340 51		167 34		310 58	18
40	313 34.1	49.6	189 49.2	288 59		343 21		170 05		313 23	20
50	316 04.1	49.7	192 19.6	291 28		345 51		172 35		315 47	21
09 00	318 34.1	S19 49.8	194 50.0	293 58	S24 10	348 21	S10 06	175 06	N 6 43	318 11	S24 23
10	321 04.0	49.9	197 20.4	296 28		350 52		177 36		320 35	25
20	323 34.0	50.0	199 50.8	298 58		353 22		180 07		322 59	26
30	326 04.0	50.1	202 21.2	301 28		355 52		182 37		325 24	28
40	328 34.0	50.2	204 51.6	303 58		358 22		185 07		327 48	29
50	331 03.9	50.3	207 22.0	306 28		0 52		187 38		330 12	31
10 00	333 33.9	S19 50.4	209 52.5	308 57	S24 10	3 22	S10 07	190 08	N 6 43	332 36	S24 32
10	336 03.9	50.5	212 22.9	311 27		5 53		192 39		335 00	34
20	338 33.9	50.6	214 53.3	313 57		8 23		195 09		337 25	35
30	341 03.8	50.7	217 23.7	316 27		10 53		197 40		339 49	37
40	343 33.8	50.8	219 54.1	318 57		13 23		200 10		342 13	38
50	346 03.8	50.8	222 24.5	321 27		15 53		202 41		344 37	40
11 00	348 33.8	S19 50.9	224 54.9	323 56	S24 11	18 23	S10 07	205 11	N 6 43	347 01	S24 41
10	351 03.7	51.0	227 25.3	326 26		20 53		207 42		349 25	43
20	353 33.7	51.1	229 55.7	328 56		23 24		210 12		351 50	44
30	356 03.7	51.2	232 26.2	331 26		25 54		212 42		354 14	46
40	358 33.6	51.3	234 56.6	333 56		28 24		215 13		356 38	47
50	1 03.6	51.4	237 27.0	336 26		30 54		217 43		359 02	49
Mean	14 52.4	50 00.6		14 59.1	50 00.3	15 00.9	50 00.6	15 02.7	50 00.1	14 25.6	50 09.7*

Lat	Moon-rise	Diff
N		
°	h m	m
72		
70		
68		
66		
64	10 35	
62	09 48	+69
60	09 17	56
58	08 54	51
56	08 36	48
54	08 21	46
52	08 07	44
50	07 55	42
45	07 31	40
40	07 12	38
35	06 56	36
30	06 42	34
20	06 19	32
10	05 59	30
0	05 40	28
10	05 22	27
20	05 02	25
30	04 39	23
35	04 26	21
40	04 11	20
45	03 53	18
50	03 31	15
52	03 20	13
54	03 09	12
56	02 55	10
58	02 40	06
60	02 21	03
S		

Moon's P. in A.

A t	C o r	A t	C o r
°	′	°	′
0	59	54	34
5	58	55	33
12	57	56	32
16	56	57	31
19	55	58	30
22	54	59	29
24	53	61	28
26	52	62	27
28	51	63	26
30	50	64	25
32	49	65	24
34	48	66	23
36	47	67	22
37	46	68	21
39	45	69	20
40	44	70	19
42	43	71	18
43	42	72	17
45	41	73	16
46	40	74	15
47	39	75	14
49	38	76	13
50	37	77	12
51	36	78	11
52	35	79	10
54	34	80	
55			

Sun SD 16′2

Moon SD 16′

Age 0d

Figure 16 SAMPLE TABLE

(DAY 325) GREENWICH P. M. 1987 NOVEMBER 21 (SATURDAY)

GMT (UT)	SUN GHA	SUN Dec	ARIES GHA	VENUS -3.9 GHA	VENUS -3.9 Dec	MARS 1.7 GHA	MARS 1.7 Dec	JUPITER -2.8 GHA	JUPITER -2.8 Dec	MOON GHA	MOON Dec
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
12 00	3 33.6	S19 51.5	239 57.4	338 55	S24 11	33 24	S10 08	220 14	N 6 43	1 26	S24 50
10	6 03.6	51.6	242 27.8	341 25		35 54		222 44		3 50	51
20	8 33.5	51.7	244 58.2	343 55		38 24		225 15		6 14	53
30	11 03.5	51.8	247 28.6	346 25		40 55		227 45		8 39	54
40	13 33.5	51.9	249 59.0	348 55		43 25		230 15		11 03	56
50	16 03.5	52.0	252 29.4	351 25		45 55		232 46		13 27	57
13 00	18 33.4	S19 52.1	254 59.8	353 55	S24 11	48 25	S10 08	235 16	N 6 43	15 51	S24 59
10	21 03.4	52.1	257 30.3	356 24		50 55		237 47		18 15	25 00
20	23 33.4	52.2	260 00.7	358 54		53 25		240 17		20 39	02
30	26 03.4	52.3	262 31.1	1 24		55 55		242 48		23 03	03
40	28 33.3	52.4	265 01.5	3 54		58 26		245 18		25 27	04
50	31 03.3	52.5	267 31.9	6 24		60 56		247 49		27 52	06
14 00	33 33.3	S19 52.6	270 02.3	8 54	S24 11	63 26	S10 09	250 19	N 6 43	30 16	S25 07
10	36 03.3	52.7	272 32.7	11 24		65 56		252 50		32 40	09
20	38 33.2	52.8	275 03.1	13 53		68 26		255 20		35 04	10
30	41 03.2	52.9	277 33.5	16 23		70 56		257 50		37 28	12
40	43 33.2	53.0	280 04.0	18 53		73 27		260 21		39 52	13
50	46 03.2	53.1	282 34.4	21 23		75 57		262 51		42 16	14
15 00	48 33.1	S19 53.2	285 04.8	23 53	S24 12	78 27	S10 10	265 22	N 6 43	44 40	S25 16
10	51 03.1	53.3	287 35.2	26 23		80 57		267 52		47 04	17
20	53 33.1	53.3	290 05.6	28 52		83 27		270 23		49 28	19
30	56 03.1	53.4	292 36.0	31 22		85 57		272 53		51 52	20
40	58 33.0	53.5	295 06.4	33 52		88 28		275 23		54 17	21
50	61 03.0	53.6	297 36.8	36 22		90 58		277 54		56 41	23
16 00	63 33.0	S19 53.7	300 07.2	38 52	S24 12	93 28	S10 10	280 24	N 6 43	59 05	S25 24
10	66 02.9	53.8	302 37.7	41 22		95 58		282 55		61 29	25
20	68 32.9	53.9	305 08.1	43 51		98 28		285 25		63 53	27
30	71 02.9	54.0	307 38.5	46 21		100 58		287 56		66 17	28
40	73 32.9	54.1	310 08.9	48 51		103 28		290 26		68 41	29
50	76 02.8	54.2	312 39.3	51 21		105 59		292 57		71 05	31
17 00	78 32.8	S19 54.3	315 09.7	53 51	S24 12	108 29	S10 11	295 27	N 6 43	73 29	S25 32
10	81 02.8	54.4	317 40.1	56 21		110 59		297 57		75 53	34
20	83 32.8	54.5	320 10.5	58 51		113 29		300 28		78 17	35
30	86 02.7	54.5	322 40.9	61 20		115 59		302 58		80 41	36
40	88 32.7	54.6	325 11.3	63 50		118 29		305 29		83 05	38
50	91 02.7	54.7	327 41.8	66 20		121 00		307 59		85 29	39
18 00	93 32.7	S19 54.8	330 12.2	68 50	S24 13	123 30	S10 11	310 30	N 6 43	87 53	S25 40
10	96 02.6	54.9	332 42.6	71 20		126 00		313 00		90 17	41
20	98 32.6	55.0	335 13.0	73 50		128 30		315 31		92 41	43
30	101 02.6	55.1	337 43.4	76 19		131 00		318 01		95 05	44
40	103 32.6	55.2	340 13.8	78 49		133 30		320 31		97 29	45
50	106 02.5	55.3	342 44.2	81 19		136 00		323 02		99 53	47
19 00	108 32.5	S19 55.4	345 14.6	83 49	S24 13	138 31	S10 12	325 32	N 6 43	102 17	S25 48
10	111 02.5	55.5	347 45.0	86 19		141 01		328 03		104 41	49
20	113 32.4	55.6	350 15.5	88 49		143 31		330 33		107 05	50
30	116 02.4	55.6	352 45.9	91 18		146 01		333 04		109 29	52
40	118 32.4	55.7	355 16.3	93 48		148 31		335 34		111 53	53
50	121 02.4	55.8	357 46.7	96 18		151 01		338 05		114 17	54
20 00	123 32.3	S19 55.9	0 17.1	98 48	S24 13	153 32	S10 13	340 35	N 6 43	116 41	S25 56
10	126 02.3	56.0	2 47.5	101 18		156 02		343 05		119 05	57
20	128 32.3	56.1	5 17.9	103 48		158 32		345 36		121 29	58
30	131 02.3	56.2	7 48.3	106 18		161 02		348 06		123 53	25 59
40	133 32.2	56.3	10 18.7	108 47		163 32		350 37		126 17	26 01
50	136 02.2	56.4	12 49.2	111 17		166 02		353 07		128 41	02
21 00	138 32.2	S19 56.5	15 19.6	113 47	S24 13	168 32	S10 13	355 38	N 6 43	131 05	S26 03
10	141 02.2	56.6	17 50.0	116 17		171 03		358 08		133 29	04
20	143 32.1	56.7	20 20.4	118 47		173 33		0 38		135 53	05
30	146 02.1	56.8	22 50.8	121 17		176 03		3 09		138 17	07
40	148 32.1	56.8	25 21.2	123 46		178 33		5 39		140 41	08
50	151 02.1	56.9	27 51.6	126 16		181 03		8 10		143 05	09
22 00	153 32.0	S19 57.0	30 22.0	128 46	S24 14	183 33	S10 14	10 40	N 6 42	145 29	S26 10
10	156 02.0	57.1	32 52.4	131 16		186 04		13 11		147 53	12
20	158 32.0	57.2	35 22.8	133 46		188 34		15 41		150 17	13
30	161 01.9	57.3	37 53.3	136 16		191 04		18 12		152 41	14
40	163 31.9	57.4	40 23.7	138 46		193 34		20 42		155 05	15
50	166 01.9	57.5	42 54.1	141 15		196 04		23 12		157 29	16
23 00	168 31.9	S19 57.6	45 24.5	143 45	S24 14	198 34	S10 14	25 43	N 6 42	159 53	S26 17
10	171 01.8	57.7	47 54.9	146 15		201 04		28 13		162 17	19
20	173 31.8	57.8	50 25.3	148 45		203 35		30 44		164 41	20
30	176 01.8	57.8	52 55.7	151 15		206 05		33 14		167 05	21
40	178 31.8	57.9	55 26.1	153 45		208 35		35 45		169 29	22
50	181 01.7	58.0	57 56.5	156 15		211 05		38 15		171 52	23
Rate	14 59.8	S0 00.6		14 59.1	S0 00.3	15 00.9	S0 00.6	15 02.6	S0 00.1	14 24.2	S0 07.9*

Lat	Moon-set	Diff.
°	h m	m
N 72		
70		
68		
66		
64	13 01	
62	13 49	−08
60	14 20	+04
58	14 43	09
56	15 02	12
54	15 18	14
52	15 32	16
50	15 44	18
45	16 09	20
40	16 30	22
35	16 47	23
30	17 01	25
20	17 26	26
10	17 48	28
0	18 08	30
10	18 28	31
20	18 50	33
30	19 15	35
35	19 30	36
40	19 48	37
45	20 09	39
50	20 35	41
52	20 48	42
54	21 03	44
56	21 21	46
58	21 42	49
60	22 09	54
S		

Moon's P. in A.

Alt	Corr	Alt	Corr
°	+	′	+
0	59	54	34
7	58	55	33
12	57	56	32
16	56	57	31
19	55	58	30
22	54	59	29
24	53	61	28
27	52	62	27
29	51	63	26
31	50	64	25
32	49	65	24
34	48	66	23
36	47	67	22
37	46	68	21
39	45	69	20
41	44	70	19
42	43	71	18
43	42	72	17
45	41	73	16
46	40	74	15
47	39	75	14
49	38	76	13
50	37	77	12
51	36	78	11
53	35	79	10
54	34	80	
55			

Sun SD 16.2

Moon SD 16′

Age 0d

Figure 17 SAMPLE TABLE

FRAME 14

Figure 13 contains moonrise and moonset tables which were taken from the daily pages. The first column of each shows the same latitudes as the sun tables. The second column gives the times of moonrise and moonset in LMT on the 180° meridian for those latitudes. Notice that there is more than six hours difference between the northernmost and southernmost times listed. This is because of the moon's orbital angle.

Because of the variability of the moon's orbital speed, there is a column to account for this difference labelled "Diff." Diff. is the half-daily difference (minutes) in local mean time for the phenomena. In simpler terms, this correction when applied to the published moonrise or set values will give you the LMT time that these events will occur at 180° longitude. NOTE: An Asterisk (*) is entered in the Diff. Column under extreme conditions where an interpolation cannot be made.

Lat	Moon-rise	Diff.
N		
°	h m	m
72	▬	*
70	10 10	32
68	09 23	32
66	08 52	32
64	08 29	32
62	08 11	32
60	07 55	32
58	07 43	32
56	07 31	31
54	07 22	32
52	07 13	32
50	07 05	31
45	06 48	31
40	06 35	31
35	06 23	31
30	06 13	31
20	05 56	31
10	05 41	31
0	05 27	31
10	05 13	31
20	04 58	30
30	04 41	30
35	04 31	30
40	04 19	30
45	04 06	30
50	03 50	29
52	03 42	29
54	03 33	29
56	03 24	29
58	03 13	29
60	03 01	29
S		

Lat	Moon set	Diff.
N		
°	h m	m
72	10 41	*
70	12 29	15
68	13 10	20
66	13 38	22
64	13 59	23
62	14 16	24
60	14 31	25
58	14 43	25
56	14 54	26
54	15 03	26
52	15 11	27
50	15 19	27
45	15 35	28
40	15 48	28
35	15 59	28
30	16 09	29
20	16 26	29
10	16 41	30
0	16 55	30
10	17 08	31
20	17 23	31
30	17 40	31
35	17 50	32
40	18 01	32
45	18 14	33
50	18 30	33
52	18 38	33
54	18 46	33
56	18 56	34
58	19 06	34
60	19 18	34
S		

Figure 13. [illegible] MOONRISE/SET TABLES

FRAME 21 (cont)

From the moonrise table (figure 18), list the LMT of moonrise at 0° and 180° longitude for the following latitudes:

	0°	180°
A. 70° N.	____	____
B. 52° S.	____	____
C. 30° N.	____	____
D. 39° N.	____	____

****

ANSWER:

A. 1010, 1042

B. 0342, 0411

C. 0613, 0644

D. 0633, 0704

FRAME 22

Now you know how to find the LMT of Moonrise/set at 0° and 180° longitude. What happens if you are located somewhere in between? You can either divide the Diff. by 180 to find the correction for each "°" or just use the table that's provided. That's right! There is a table provided in the Air Almanac to assist you in interpolating for longitudes other then 0° and 180°. An example of this table, entitled Interpolation of Moonrise, Moonset for Longitudes is reproduced in Figure 19.

Notice that the table actually consists of 3 vertically stacked sections. The top table lists Diff. values from 5-30, the mid level 35-60, and finally values from 65-90. The longitudes are listed along the left side. The 0° longitude value will always be zero and the value at 180° will always be the same as the value at the head of the column.

FRAME 32 (contd)

To obtain the time difference for your location, use the Diff. value you derived from the moonrise/set tables and the longitude value nearest your location the correction amount is accurate enough so that further interpolation is not necessary.

F4 INTERPOLATION OF MOONRISE, MOONSET

FOR LONGITUDE

Add if longitude west
Subtract if longitude east

Longitude	Diff.* 06	10	15	20	25	30
°	m	m	m	m	m	m
0	00	00	00	00	00	00
20	01	01	02	02	03	03
40	01	02	03	04	05	07
60	02	03	05	07	08	10
80	02	04	07	09	11	13
100	03	06	08	11	14	17
120	03	07	10	13	17	20
140	04	08	12	16	19	23
160	04	09	13	18	22	27
180	06	10	15	20	25	30

Longitude	Diff.* 35	40	45	50	55	60
°	m	m	m	m	m	m
0	00	00	00	00	00	00
15	03	03	04	04	05	05
30	06	07	08	08	09	10
45	09	10	11	12	14	15
60	12	13	15	17	18	20
75	15	17	19	21	23	25
90	18	20	22	25	28	30
105	20	23	26	29	32	35
120	23	27	30	33	37	40
135	26	30	34	38	41	45
150	29	33	38	42	46	50
165	32	37	41	46	50	55
180	35	40	45	50	55	60

Longitude	Diff.* 65	70	75	80	85	90
°	m	m	m	m	m	m
0	00	00	00	00	00	00
15	04	04	04	04	05	05
30	07	08	08	09	09	10
45	11	12	12	13	14	15
60	14	16	17	18	19	20
75	18	19	21	22	24	25
90	22	23	25	27	28	30
105	25	27	29	31	33	35
120	29	31	33	36	38	40
135	32	35	38	40	42	45
150	36	39	42	44	47	50
165	40	43	46	49	52	55
180	43	47	50	53	57	60
195	47	51	54	58	61	65
210	51	54	58	62	66	70
225	54	58	62	67	71	75
240	58	62	67	71	76	80
255	61	66	71	76	80	85
270	65	70	75	80	85	90

* When negative subtract correction if longitude west and add if east.

For example, if your Diff. value from the daily pages was 37 and your longitude was 87° West, you would use a Diff. value of 35 and enter the table at 90° longitude to get a correction of + 18 minutes. It is "+" because you're at West Longitude. Select the correction factor from the interpolation table for the following Diff. values and longitudes. When the daily tables indicate a "POSITIVE " Diff. value indicate "+" if the correction is West/ "-" if the correction is East.

EXCEPTION: If the Diff. value in the daily tables is negative "-" then you subtract the correction from the LMT when you are at West longitude and add it if you are East.

	DIFF.	LONG. CORR.
A.	25	100 W.
B.	-7	68 W.
C.	42	122 E.
D.	-16	15 E.

****

ANSWER:

A. +14 C. -27

B. -2 D. +2

Figure 19. Interpolation of Moonrise, Moonset for Longitude.

FRAME 23

To complete the process of obtaining moonrise/set times, use the Conversion of Arc to Time Table from the Almanac (or Figure 5) to convert to LST, at your position, as you did for sun times.
NOTE: Each month there is one day near the first quarter without a moonset and one day near the last quarter without a moonrise. The tabulated times may indicate more than 24 hours (e.g. 24hr 38 min.), or, after conversion, the LST may be over 24 hours (i.e. the next day).

NO RESPONSE NECESSARY

FRAME 24

Using the moonrise and moonset tables for 21 November, shown in pages 31 and 32, the Interpolation for Moonrise, Moonset for Longitude Table (Figure 19), the Conversion of Arc to Time Table (Figure 5), and the conversion tables for Standard time (Air Almanac) find moonrise/set times for the following stations in LST.

			Moonrise/Set
A. Langley AFB, Va	(37° 05' N.	76° 21' W.)	_____/_____
B. Fulda, FRG	(50° 33' N.	9° 41' E.)	_____/_____
C. Osan, Korea	(37° 06' N.	127° 02' E.)	_____/_____

ANSWER:

A. 0724/1655

B. 0818/1601

C. 0709/1657

FRAME 25

Moon phase data are shown at the top of the daily pages in the Almanac. The symbols are related to the phase symbols in Figure 12. At the bottom right of each daily page, the number of days since the last New Moon are given as "Age(#)d." Finally, Fractional Illumination data are also provided in the Air Almanac (see List of Contents).

NO RESPONSE NECESSARY

FRAME 26

For latitudes between 65° and 90° North, Semiduration of Moonlight graphs are provided in the Almanac. These tables are very similar to the Semiduration of Sunlight graphs. Each 'moon' has its own graph.

FRAME 26 (CONTD)

A December 1987 graph is shown in Figure 20. Dates are shown across the bottom and top and meridian passage times are indicated near the top of the chart by dots (.) at one hour intervals. The skewed semiduration lines are similar to those in the sunlight graph, as are the moon above and moon below horizon portions of the graph. Moon phases are indicated on their date of occurrence. Note that the phases correspond to meridian passage times (6 hours apart) and are the same as illustrated in Figure 12. You'll need to keep Figure 12 in mind to ensure the rise/set times are figured for the "correct" day. For example, on 6 December there is a full moon. As depicted in Fig. 12 a full moon passes the meridian near midnight. At 70° North on 6 December, Fig.20 shows that the moon is (continuously) above the horizon. There is, therefore, neither rise nor set on 6 December, but there is continuous moonlight. On 13 December the moon is near third quarter (figs. 12 and 20) and so it passes the meridian near 0600. From Fig. 20, the semiduration of moonlight for latitude 75° North on 13 December is approximately 8 hours. Thus, moonrise is on December 12 at approximately 2200 and moonset on 13 December is approximately at 1400 for latitude 75°.

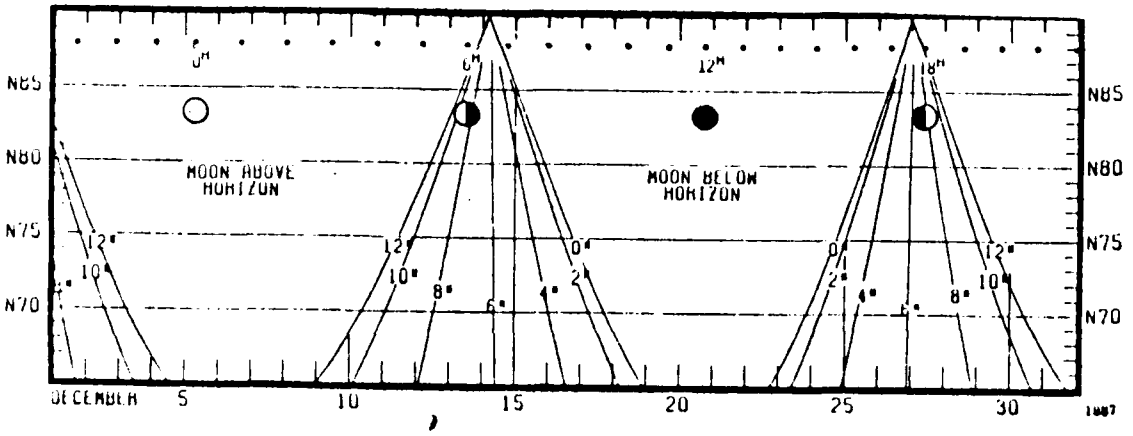


Figure 20. Semiduration of Moonlight

FRAME 26 (CONTD)

Find the LMT of moonrise and moonset for the following dates and latitudes:

	MOONRISE/MOONSET
A. 10 Dec, 74° N.	_____ / _____
B. 25 Dec, 80° N.	_____ / _____
C. 27 Dec, 70° N.	_____ / _____
D. 17 Dec, 69° N.	_____ / _____

****

ANSWER:

A. moon above the horizon.

B. moon below the horizon.

C. 1130, 2330

D. 0559, 1159

TEST QUESTIONS

The following test is provided so you can determine whether or not you reached the objectives stated in the beginning of this Tech Note. Tables and graphs to be used for this test are located on the following pages.

1. State the main reason that sunrise, sunset, and twilight times change from day-to-day.

_____

_____

_____

_____

_____

2. Langley AFB, VA is located at 37° 05' N, 76° 21' N. List the Local Standard Time on 15 April that the following events will occur:

AM Civ Twilight	Sunrise	Sunset	PM Civ Twilight

3. State the Local Mean Time of occurrence at 75° N. on 1 April for the following events:

AM Civ Twilight	Sunrise	Sunset	PM Civ Twilight

4. Name two factors that cause moonrise/set times to change from day to day.

A. _____

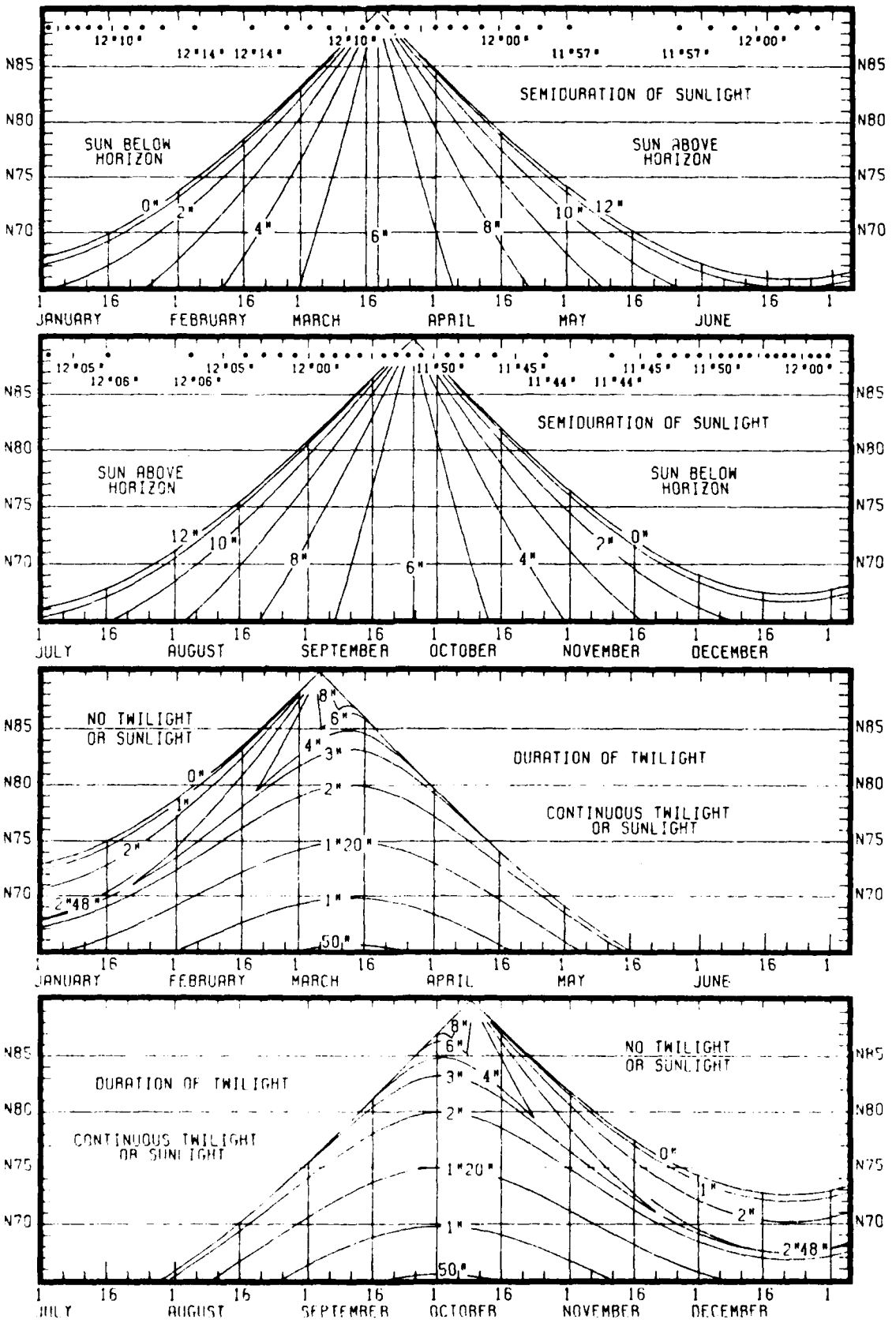
B. _____

5. Fulda Gap, FRG is located at 50° 33' N, 9° 41' E. Figure the time of occurrence of the following events on 15 Apr 87.

Moonrise	Moonset
GMT	GMT
LST	LST

6. State the Local Mean Time of moonrise and set at 75° N. on 7 May 87.

Moonrise	Moonset


12°10'
12°14'
12°14'
12°10'
12°00'
11°57'
11°57'
12°00'
SEMIDURATION OF SUNLIGHT
SUN BELOW HORIZON
SUN ABOVE HORIZON
0°
2°
4°
6°
8°
10°
12°
N85
N80
N75
N70
1
16
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
12°05'
12°06'
12°06'
12°05'
12°00'
11°50'
11°45'
11°44'
11°44'
11°45'
11°50'
12°00'
SEMIDURATION OF SUNLIGHT
SUN ABOVE HORIZON
SUN BELOW HORIZON
12°
10°
8°
6°
4°
2°
0°
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
NO TWILIGHT OR SUNLIGHT
DURATION OF TWILIGHT
CONTINUOUS TWILIGHT OR SUNLIGHT
8°
6°
4°
3°
2°
1°20°
1°
50°
0°
1°
2°
2°48°
DURATION OF TWILIGHT
CONTINUOUS TWILIGHT OR SUNLIGHT
NO TWILIGHT OR SUNLIGHT

°	h m	°	h m	°	h m	°	h m	°	h m	°	h m	′	m s
0	0 00	60	4 00	120	8 00	180	12 00	240	16 00	300	20 00	0	0 00
1	0 04	61	4 04	121	8 04	181	12 04	241	16 04	301	20 04	1	0 04
2	0 08	62	4 08	122	8 08	182	12 08	242	16 08	302	20 08	2	0 08
3	0 12	63	4 12	123	8 12	183	12 12	243	16 12	303	20 12	3	0 12
4	0 16	64	4 16	124	8 16	184	12 16	244	16 16	304	20 16	4	0 16
5	0 20	65	4 20	125	8 20	185	12 20	245	16 20	305	20 20	5	0 20
6	0 24	66	4 24	126	8 24	186	12 24	246	16 24	306	20 24	6	0 24
7	0 28	67	4 28	127	8 28	187	12 28	247	16 28	307	20 28	7	0 28
8	0 32	68	4 32	128	8 32	188	12 32	248	16 32	308	20 32	8	0 32
9	0 36	69	4 36	129	8 36	189	12 36	249	16 36	309	20 36	9	0 36
10	0 40	70	4 40	130	8 40	190	12 40	250	16 40	310	20 40	10	0 40
11	0 44	71	4 44	131	8 44	191	12 44	251	16 44	311	20 44	11	0 44
12	0 48	72	4 48	132	8 48	192	12 48	252	16 48	312	20 48	12	0 48
13	0 52	73	4 52	133	8 52	193	12 52	253	16 52	313	20 52	13	0 52
14	0 56	74	4 56	134	8 56	194	12 56	254	16 56	314	20 56	14	0 56
15	1 00	75	5 00	135	9 00	195	13 00	255	17 00	315	21 00	15	1 00
16	1 04	76	5 04	136	9 04	196	13 04	256	17 04	316	21 04	16	1 04
17	1 08	77	5 08	137	9 08	197	13 08	257	17 08	317	21 08	17	1 08
18	1 12	78	5 12	138	9 12	198	13 12	258	17 12	318	21 12	18	1 12
19	1 16	79	5 16	139	9 16	199	13 16	259	17 16	319	21 16	19	1 16
20	1 20	80	5 20	140	9 20	200	13 20	260	17 20	320	21 20	20	1 20
21	1 24	81	5 24	141	9 24	201	13 24	261	17 24	321	21 24	21	1 24
22	1 28	82	5 28	142	9 28	202	13 28	262	17 28	322	21 28	22	1 28
23	1 32	83	5 32	143	9 32	203	13 32	263	17 32	323	21 32	23	1 32
24	1 36	84	5 36	144	9 36	204	13 36	264	17 36	324	21 36	24	1 36
25	1 40	85	5 40	145	9 40	205	13 40	265	17 40	325	21 40	25	1 40
26	1 44	86	5 44	146	9 44	206	13 44	266	17 44	326	21 44	26	1 44
27	1 48	87	5 48	147	9 48	207	13 48	267	17 48	327	21 48	27	1 48
28	1 52	88	5 52	148	9 52	208	13 52	268	17 52	328	21 52	28	1 52
29	1 56	89	5 56	149	9 56	209	13 56	269	17 56	329	21 56	29	1 56
30	2 00	90	6 00	150	10 00	210	14 00	270	18 00	330	22 00	30	2 00
31	2 04	91	6 04	151	10 04	211	14 04	271	18 04	331	22 04	31	2 04
32	2 08	92	6 08	152	10 08	212	14 08	272	18 08	332	22 08	32	2 08
33	2 12	93	6 12	153	10 12	213	14 12	273	18 12	333	22 12	33	2 12
34	2 16	94	6 16	154	10 16	214	14 16	274	18 16	334	22 16	34	2 16
35	2 20	95	6 20	155	10 20	215	14 20	275	18 20	335	22 20	35	2 20
36	2 24	96	6 24	156	10 24	216	14 24	276	18 24	336	22 24	36	2 24
37	2 28	97	6 28	157	10 28	217	14 28	277	18 28	337	22 28	37	2 28
38	2 32	98	6 32	158	10 32	218	14 32	278	18 32	338	22 32	38	2 32
39	2 36	99	6 36	159	10 36	219	14 36	279	18 36	339	22 36	39	2 36
40	2 40	100	6 40	160	10 40	220	14 40	280	18 40	340	22 40	40	2 40
41	2 44	101	6 44	161	10 44	221	14 44	281	18 44	341	22 44	41	2 44
42	2 48	102	6 48	162	10 48	222	14 48	282	18 48	342	22 48	42	2 48
43	2 52	103	6 52	163	10 52	223	14 52	283	18 52	343	22 52	43	2 52
44	2 56	104	6 56	164	10 56	224	14 56	284	18 56	344	22 56	44	2 56
45	3 00	105	7 00	165	11 00	225	15 00	285	19 00	345	23 00	45	3 00
46	3 04	106	7 04	166	11 04	226	15 04	286	19 04	346	23 04	46	3 04
47	3 08	107	7 08	167	11 08	227	15 08	287	19 08	347	23 08	47	3 08
48	3 12	108	7 12	168	11 12	228	15 12	288	19 12	348	23 12	48	3 12
49	3 16	109	7 16	169	11 16	229	15 16	289	19 16	349	23 16	49	3 16
50	3 20	110	7 20	170	11 20	230	15 20	290	19 20	350	23 20	50	3 20
51	3 24	111	7 24	171	11 24	231	15 24	291	19 24	351	23 24	51	3 24
52	3 28	112	7 28	172	11 28	232	15 28	292	19 28	352	23 28	52	3 28
53	3 32	113	7 32	173	11 32	233	15 32	293	19 32	353	23 32	53	3 32
54	3 36	114	7 36	174	11 36	234	15 36	294	19 36	354	23 36	54	3 36
55	3 40	115	7 40	175	11 40	235	15 40	295	19 40	355	23 40	55	3 40
56	3 44	116	7 44	176	11 44	236	15 44	296	19 44	356	23 44	56	3 44
57	3 48	117	7 48	177	11 48	237	15 48	297	19 48	357	23 48	57	3 48
58	3 52	118	7 52	178	11 52	238	15 52	298	19 52	358	23 52	58	3 52
59	3 56	119	7 56	179	11 56	239	15 56	299	19 56	359	23 56	59	3 56

The above table is for converting expressions in arc to their equivalent in time; its main use in this Almanac is for the conversion of longitude for application to L.M.T. (*added* if *west*, *subtracted* if *east*) to give G.M.T., or vice versa, particularly in the case of sunrise, sunset, etc.

SUNRISE

Lat.	April 2	5	8	11	14	17	20	23	26	29	May 2	5	8	11	14	17
	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m
N 72	04 [illegible]	04 30	04 23	04 05	03 49	03 32	03 14	02 55	02 35	02 14	01 50	01 22	00 41	- -	- -	- -
70	05 02	48	34	19	04 05	03 50	35	03 19	03 03	02 47	02 29	02 11	01 51	01 29	01 02	00 12
68	05	04 56	43	30	17	04 04	03 51	37	24	03 10	02 59	02 42	02 28	02 12	01 57	01 40
66	14	05 02	50	39	27	15	04 04	03 52	40	28	03 17	03 05	02 53	02 41	02 29	02 17
64	18	07	04 57	46	35	25	14	04 04	03 53	43	33	23	03 12	03 02	02 53	02 43
62	22	12	05 02	52	43	33	23	14	04 05	03 55	46	37	28	20	03 11	03 03
N 60	05 25	05 16	05 07	04 58	04 49	04 40	04 31	04 22	04 14	04 05	03 57	03 49	03 41	03 34	03 26	03 19
58	28	19	11	05 02	54	46	38	30	22	15	04 07	04 00	03 53	46	39	33
56	30	22	14	07	04 59	51	44	37	29	22	16	09	04 02	03 56	03 50	45
54	32	25	18	11	05 03	04 56	49	43	36	29	23	17	11	04 06	04 00	03 55
52	34	28	21	14	07	05 01	04 54	48	42	36	30	24	19	14	09	04 04
N 50	05 36	05 30	05 24	05 17	05 11	05 05	04 59	04 53	04 47	04 41	04 36	04 31	04 26	04 21	04 17	04 12
45	40	35	29	24	19	13	05 08	05 03	04 58	04 54	04 49	45	41	37	33	30
40	44	39	34	30	25	21	16	12	05 08	05 04	05 00	04 56	04 53	04 49	46	44
35	47	43	38	34	30	27	23	19	16	12	09	05 06	05 03	05 00	04 58	04 56
30	49	46	42	39	35	32	29	26	23	20	17	14	12	10	05 08	05 06
N 20	05 53	05 51	05 48	05 46	05 43	05 41	05 39	05 36	05 34	05 32	05 31	05 29	05 27	05 26	05 25	05 23
N 10	05 57	05 55	54	52	51	49	47	46	45	44	43	42	41	40	39	39
0	06 01	06 00	05 59	05 58	05 57	05 56	05 56	05 55	05 55	05 54	05 54	05 53	05 53	05 53	05 53	05 53
S 10	04	04	06 04	06 04	06 04	06 04	06 04	06 04	06 04	06 04	06 04	06 05	06 05	06 06	06 06	06 07
20	07	08	09	09	10	11	12	13	14	15	16	17	18	19	20	21
S 30	06 11	06 12	06 14	06 16	06 18	06 20	06 22	06 23	06 25	06 27	06 29	06 31	06 33	06 35	06 37	06 38
35	13	15	18	20	22	25	27	29	32	34	37	39	41	44	46	48
40	15	18	21	24	27	30	33	36	39	42	45	48	06 51	06 54	06 57	06 59
45	18	22	25	29	33	37	40	44	48	06 51	06 55	06 59	07 02	07 06	07 09	07 12
50	21	26	30	35	40	44	49	53	06 58	07 02	07 07	07 11	16	20	24	28
S 52	06 22	06 28	06 33	06 38	06 43	06 48	06 53	06 58	07 03	07 08	07 12	07 17	07 22	07 27	07 31	07 36
54	24	30	35	41	46	51	06 57	07 02	08	13	19	24	29	34	39	44
56	26	32	38	44	50	06 56	07 02	08	14	20	25	31	37	42	48	07 53
58	28	34	41	47	54	07 00	07	14	20	26	33	39	46	07 52	07 58	08 04
S 60	06 30	06 37	06 44	06 51	06 58	07 06	07 13	07 20	07 27	07 34	07 41	07 49	07 56	08 03	08 09	08 16

SUNSET

Lat.	April 2	5	8	11	14	17	20	23	26	29	May 2	5	8	11	14	17
	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m
N 72	19 16	19 30	19 45	20 00	20 16	20 32	20 48	21 06	21 26	21 47	22 11	22 41	23 35	[illegible]	[illegible]	[illegible]
70	08	21	33	19 46	20 00	20 13	27	20 42	20 57	21 12	21 29	21 47	22 07	22 31	23 01	[illegible]
68	19 02	13	24	35	19 47	19 59	20 11	23	35	20 48	21 01	21 15	21 30	21 45	22 01	22 18
66	18 56	06	16	26	37	47	19 57	20 08	18	29	20 40	20 52	21 03	21 15	21 27	21 39
64	52	19 01	10	19	28	37	46	19 55	20 05	14	24	33	20 43	20 53	21 02	21 12
62	48	18 56	19 04	12	20	29	37	45	19 53	20 02	20 10	18	27	35	20 43	20 51
N 60	18 44	18 52	18 59	19 06	19 14	19 21	19 29	19 36	19 44	19 51	19 59	20 06	20 13	20 21	20 28	20 35
58	41	48	55	19 01	08	15	22	28	35	42	48	19 55	20 02	20 08	15	21
56	39	45	51	18 57	19 03	09	16	22	28	34	40	46	19 52	19 58	20 03	20 09
54	36	42	47	53	18 59	04	10	16	21	27	32	38	43	48	19 53	19 58
52	34	39	44	50	55	19 00	05	10	15	20	25	30	35	40	45	49
N 50	18 32	18 37	18 42	18 48	18 54	18 59	19 04	19 09	19 14	19 19	19 24	19 29	19 33	19 37	19 41	
45	28	32	36	39	43	47	18 51	18 55	18 58	19 02	19 06	19 09	13	17	20	24
40	24	28	31	34	37	40	43	46	49	18 52	18 55	18 58	19 01	19 04	19 07	19 09
35	22	24	26	29	31	33	36	38	41	43	46	48	18 50	18 53	18 55	18 58
30	19	21	22	24	26	28	30	32	34	36	37	39	41	43	45	47
N 20	18 14	18 15	18 16	18 17	18 18	18 19	18 20	18 21	18 22	18 23	18 24	18 25	18 26	18 27	18 28	18 29
N 10	10	10	10	10	10	11	11	11	11	11	12	12	13	13	14	14
0	07	06	05	18 04	18 04	18 03	18 02	18 02	18 01	18 01	18 00	18 00	18 00	18 00	18 00	18 00
S 10	04	18 02	18 00	17 59	17 57	17 56	17 54	17 53	17 52	17 51	17 50	17 49	17 48	17 47	17 46	17 46
20	18 00	17 58	17 55	53	50	48	46	44	42	40	38	36	35	33	32	31
S 30	17 56	17 53	17 49	17 46	17 43	17 39	17 36	17 33	17 30	17 27	17 25	17 22	17 20	17 18	17 16	17 14
35	51	50	46	42	38	34	31	27	23	20	17	14	11	17 09	17 06	17 04
40	46	47	42	38	33	29	24	20	16	12	17 09	17 05	17 02	16 59	16 56	16 53
45	40	43	38	33	27	22	17	12	17 07	17 03	16 58	16 54	16 50	47	43	40
50	40	39	33	27	20	14	09	17 03	16 57	16 52	47	42	37	32	28	24
S 52	17 44	17 37	17 31	17 24	17 17	17 11	17 05	16 58	16 52	16 47	16 41	16 35	16 30	16 25	16 21	16 16
54	43	35	28	21	14	07	17 00	54	47	41	35	29	23	18	13	16 08
56	41	33	25	18	10	17 03	16 56	48	41	35	28	22	15	10	16 04	15 59
58	39	30	22	14	06	16 58	50	43	35	28	20	13	16 07	16 00	15 54	48
S 60	17 37	17 28	17 19	17 10	17 01	16 53	16 44	16 36	16 28	16 19	16 12	16 04	15 56	15 49	15 43	15 36

MORNING CIVIL TWILIGHT

Lat.	April 2	5	8	11	14	17	20	23	26	29	May 2	5	8	11	14	17
	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m
N 72	03 42	03 21	03 03	02 48	02 34	02 21	02 08									
70	03 50	03	02	02	02	02	02	01	01							
68	04 00	03	03	02	02	02	01	01	01	01	01	00				
66	04	03	03	02	02	02	01	01	01	01	01	01	00			
64	04	03	03	02	02	01	01	01	01	01	01	01	01	00	00	
62	04	03	03	02	02	01	01	01	01	01	01	01	01	01	00	00
N 60	04 12	04 02	03 53	03 44	03 36	03 28	03 20	03 13	03 06	02 59	02 53	02 47	02 41	02 35	02 30	02 25
58	04	03	03	03	03	02	02	02	02	02	02	02	02	02	02	02
56	04	03	03	03	02	02	02	02	02	02	02	02	02	02	02	02
54	04	04	03	03	03	03	02	02	02	02	02	02	02	02	02	02
52	04	04	04	03	03	03	03	03	02	02	02	02	02	02	02	02
N 50	04	04	04	04	03	03	03	03	03	03	03	03	03	03	03	03
45	04	04	04	04	04	04	04	03	03	03	03	03	03	03	03	03
40	05	04	04	04	04	04	04	04	04	03	03	03	03	03	03	03
35	05	05	04	04	04	04	04	04	04	04	04	04	04	03	03	03
30	05	05	05	04	04	04	04	04	04	04	04	04	04	04	04	04
N 20	05 31	05 29	05 26	05 24	05 21	05 19	05 17	05 14	05 12	05 10	05 08	05 06	05 04	05 03	05 01	05 00
N 10	05	05	05	05	05	05	05	05	05	05	05	05	05	05	05	05
0	05	05	05	05	05	05	05	05	05	05	05	05	05	05	05	05
S 10	05	05	05	05	05	05	05	05	05	05	05	05	05	05	05	05
20	05	05	05	05	05	05	05	05	05 51	05 52	05 53	05 54	05 55	05 56	05 57	05 58
S 30	05 47	05 49	05 50	05 52	05 54	05 56	05 57	05 59	06 01	06 03	06 04	06 06	06 08	06 10	06 11	06 13
35	05	05	05	05	05	05	05	06 01	06 04	06	06	06	06	06	06	06
40	05	05	05	05	05	06 00	06 03	06	06	06	06	06	06	06	06	06
45	05	05	05	05	06 00	06	06	06	06	06	06	06	06	06	06	06
50	05	05	05	06	06	06	06	06	06	06	06	06	06	06	06	06
S 52	05 49	05 54	05 59	06 04	06 08	06 13	06 18	06 23	06 27	06 32	06 37	06 41	06 45	06 50	06 54	06 58
54	05	05	06 00	06	06	06	06	06	06	06	06	06	06	06	07	07
56	05	05	06	06	06	06	06	06	06	06	06	06	07	07	07	07
58	05	05	06	06	06	06	06	06	06	06	06	07	07	07	07	07
S 60	05 48	05 55	06 02	06 06	06 10	06 15	06 20	06 25	06 30	06 36	06 43	06 49	06 56	07 02	07 08	07 14

EVENING CIVIL TWILIGHT

Lat.	April 2	5	8	11	14	17	20	23	26	29	May 2	5	8	11	14	17
	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m
N 72	20 32	20 50	21 09	21 31	21 55	22 24	23 06									
70	15	30	20 45	21 02	21 20	21 39	22 02	22 28	23 07							
68	20 02	14	28	20 41	20 56	21 11	21 27	21 45	22 05	22 29	23 01					
66	19 51	20 02	13	25	37	20 50	21 03	21 17	21 32	21 48	22 06	22 26	22 51	23 33		
64	42	19 52	20 02	12	22	33	20 44	20 56	21 08	21	21 34	21 48	22 03	22 20	22 39	23 02
62	34	43	19 52	20 01	10	20	29	39	20 49	21 00	21 11	22	21 33	21 45	21 58	22 11
N 60	19 28	19 36	19 44	19 52	20 00	20 08	20 17	20 25	20 34	20 43	20 53	21 02	21 11	21 21	21 30	21 40
58	22	29	36	44	19 51	19 59	20 06	14	22	30	38	20 45	20 54	21 02	21 10	18
56	17	23	30	37	43	50	19 57	20 04	11	18	25	32	39	20 46	20 53	21 00
54	13	18	24	30	36	43	49	19 55	20 01	20 08	14	20	26	33	39	20 45
52	09	14	20	25	31	36	42	47	19 53	19 59	20 04	10	16	21	27	32
N 50	19 05	19 10	19 15	19 20	19 25	19 30	19 35	19 40	19 46	19 51	19 56	20 01	20 06	20 11	20 16	20 21
45	18 58	19 02	19 06	10	14	18	22	26	30	34	38	19 42	19 46	19 50	19 54	19 58
40	52	18 55	18 58	19 02	19 05	08	11	14	18	21	24	28	31	34	37	40
35	47	49	52	18 54	18 57	19 00	19 02	19 05	19 07	10	13	15	18	21	23	26
30	43	45	47	49	51	18 53	18 55	18 57	18 59	19 01	19 03	19 05	19 07	19 09	19 11	19 13
N 20	18 37	18 37	18 38	18 39	18 40	18 41	18 42	18 43	18 44	18 46	18 47	18 48	18 49	18 50	18 52	18 53
N 10	32	32	32	32	32	32	32	32	33	33	33	34	34	35	36	36
0	28	27	26	25	25	24	23	23	23	22	22	22	22	22	22	22
S 10	25	23	22	20	19	17	16	14	13	12	11	18 10	18 09	18 09	18 08	18 08
20	22	20	17	15	13	10	08	18 06	18 04	18 02	18 01	17 59	17 58	17 56	17 55	17 54
S 30	18 20	18 17	18 13	18 10	18 07	18 03	18 00	17 58	17 55	17 52	17 49	17 47	17 45	17 43	17 41	17 39
35	19	15	11	07	04	18 00	17 56	53	50	46	43	41	38	35	33	31
40	19	14	09	05	18 00	17 56	52	48	44	40	37	34	30	27	25	22
45	18	13	07	18 02	17 57	52	47	42	38	33	29	25	22	18	15	12
50	18	12	06	17 59	53	47	42	36	31	26	21	16	12	07	17 03	17 00
S 52	18 18	18 11	18 04	17 58	17 52	17 45	17 39	17 33	17 28	17 22	17 17	17 12	17 07	17 02	16 58	16 54
54	18	11	04	57	50	43	37	30	24	18	13	07	17 02	16 57	52	48
56	18	10	03	55	48	41	34	27	20	14	08	17 02	16 56	51	46	42
58	18	10	02	54	46	38	31	24	16	10	17 03	16 57	51	45	39	34
S 60	18 18	18 09	18 01	17 52	17 44	17 35	17 27	17 20	17 12	17 05	16 57	16 50	16 44	16 38	16 32	16 26

GMT (UT)	SUN GHA	SUN Dec	ARIES GHA	VENUS -4.0 GHA	VENUS -4.0 Dec	MARS 1.5 GHA	MARS 1.5 Dec	JUPITER -2.0 GHA	JUPITER -2.0 Dec	MOON GHA	MOON Dec
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
00 00	179 55.7	N 9 29.8	202 37.2	210 35	S 4 52	138 26	N22 14	192 38	N 3 07	349 44	S15 35
10	182 25.7	30.0	205 07.6	213 05		140 57		195 09		352 09	37
20	184 55.7	30.1	207 38.0	215 35		143 27		197 39		354 34	40
30	187 25.8	30.3	210 08.5	218 05		145 57		200 09		356 59	42
40	189 55.8	30.4	212 38.9	220 35		148 27		202 40		359 24	44
50	192 25.8	30.6	215 09.3	223 05		150 57		205 10		1 48	47
01 00	194 55.8	N 9 30.7	217 39.7	225 35	S 4 51	153 27	N22 14	207 40	N 3 07	4 13	S15 49
10	197 25.9	30.9	220 10.1	228 05		155 57		210 11		6 38	52
20	199 55.9	31.0	222 40.5	230 35		158 27		212 41		9 03	54
30	202 25.9	31.2	225 10.9	233 04		160 58		215 11		11 28	56
40	204 55.9	31.3	227 41.3	235 34		163 28		217 41		13 53	15 59
50	207 26.0	31.5	230 11.7	238 04		165 58		220 12		16 18	16 01
02 00	209 56.0	N 9 31.6	232 42.1	240 34	S 4 50	168 28	N22 15	222 42	N 3 07	18 43	S16 03
10	212 26.0	31.8	235 12.6	243 04		170 58		225 13		21 08	06
20	214 56.0	31.9	237 43.0	245 34		173 28		227 43		23 32	08
30	217 26.1	32.1	240 13.4	248 04		175 58		230 13		25 57	11
40	219 56.1	32.2	242 43.8	250 34		178 28		232 43		28 22	13
50	222 26.1	32.4	245 14.2	253 04		180 58		235 14		30 47	15
03 00	224 56.1	N 9 32.5	247 44.6	255 34	S 4 49	183 29	N22 15	237 44	N 3 08	33 12	S16 18
10	227 26.2	32.7	250 15.0	258 04		185 59		240 14		35 37	20
20	229 56.2	32.8	252 45.4	260 34		188 29		242 45		38 02	22
30	232 26.2	33.0	255 15.8	263 04		190 59		245 15		40 27	25
40	234 56.2	33.1	257 46.3	265 34		193 29		247 45		42 51	27
50	237 26.3	33.3	260 16.7	268 04		195 59		250 16		45 16	29
04 00	239 56.3	N 9 33.4	262 47.1	270 34	S 4 48	198 29	N22 15	252 46	N 3 08	47 41	S16 32
10	242 26.3	33.6	265 17.5	273 04		200 59		255 16		50 06	34
20	244 56.4	33.7	267 47.9	275 34		203 29		257 47		52 31	36
30	247 26.4	33.9	270 18.3	278 03		206 00		260 17		54 56	39
40	249 56.4	34.0	272 48.7	280 33		208 30		262 47		57 21	41
50	252 26.4	34.2	275 19.1	283 03		211 00		265 18		59 45	43
05 00	254 56.5	N 9 34.3	277 49.5	285 33	S 4 47	213 30	N22 16	267 48	N 3 08	62 10	S16 46
10	257 26.5	34.5	280 20.0	288 03		216 00		270 18		64 35	48
20	259 56.5	34.6	282 50.4	290 33		218 30		272 48		67 00	50
30	262 26.5	34.8	285 20.8	293 03		221 00		275 19		69 25	53
40	264 56.6	34.9	287 51.2	295 33		223 30		277 49		71 50	55
50	267 26.6	35.1	290 21.6	298 03		226 01		280 19		74 14	16 57
06 00	269 56.6	N 9 35.2	292 52.0	300 33	S 4 46	228 31	N22 16	282 50	N 3 08	76 39	S17 00
10	272 26.6	35.4	295 22.4	303 03		231 01		285 20		79 04	02
20	274 56.7	35.5	297 52.8	305 33		233 31		287 50		81 29	04
30	277 26.7	35.7	300 23.2	308 03		236 01		290 21		83 54	07
40	279 56.7	35.8	302 53.6	310 33		238 31		292 51		86 18	09
50	282 26.7	36.0	305 24.1	313 03		241 01		295 21		88 43	11
07 00	284 56.8	N 9 36.1	307 54.5	315 33	S 4 44	243 31	N22 16	297 52	N 3 08	91 08	S17 13
10	287 26.8	36.3	310 24.9	318 03		246 01		300 22		93 33	16
20	289 56.8	36.4	312 55.3	320 33		248 32		302 52		95 58	18
30	292 26.8	36.6	315 25.7	323 03		251 02		305 23		98 22	20
40	294 56.9	36.7	317 56.1	325 32		253 32		307 53		100 47	23
50	297 26.9	36.9	320 26.5	328 02		256 02		310 23		103 12	25
08 00	299 56.9	N 9 37.0	322 56.9	330 32	S 4 43	258 32	N22 16	312 54	N 3 09	105 37	S17 27
10	302 26.9	37.1	325 27.3	333 02		261 02		315 24		108 02	29
20	304 57.0	37.3	327 57.8	335 32		263 32		317 54		110 26	32
30	307 27.0	37.4	330 28.2	338 02		266 02		320 25		112 51	34
40	309 57.0	37.6	332 58.6	340 32		268 33		322 55		115 16	36
50	312 27.0	37.7	335 29.0	343 02		271 03		325 25		117 41	39
09 00	314 57.1	N 9 37.9	337 59.4	345 32	S 4 42	273 33	N22 17	327 56	N 3 09	120 05	S17 41
10	317 27.1	38.0	340 29.8	348 02		276 03		330 26		122 30	43
20	319 57.1	38.2	343 00.2	350 32		278 33		332 56		124 55	45
30	322 27.1	38.3	345 30.6	353 02		281 03		335 27		127 20	48
40	324 57.2	38.5	348 01.0	355 32		283 33		337 57		129 44	50
50	327 27.2	38.6	350 31.4	358 02		286 03		340 27		132 09	52
10 00	329 57.2	N 9 38.8	353 01.9	0 32	S 4 41	288 33	N22 17	342 57	N 3 09	134 34	S17 54
10	332 27.3	38.9	355 32.3	3 02		291 04		345 28		136 59	57
20	334 57.3	39.1	358 02.7	5 32		293 34		347 58		139 23	17 59
30	337 27.3	39.2	0 33.1	8 02		296 04		350 28		141 48	18 01
40	339 57.3	39.4	3 03.5	10 31		298 34		352 59		144 13	03
50	342 27.4	39.5	5 33.9	13 01		301 04		355 29		146 38	06
11 00	344 57.4	N 9 39.7	8 04.3	15 31	S 4 40	303 34	N22 17	357 59	N 3 09	149 02	S18 08
10	347 27.4	39.8	10 34.7	18 01		306 04		0 30		151 27	10
20	349 57.4	40.0	13 05.1	20 31		308 34		3 00		153 52	12
30	352 27.5	40.1	15 35.6	23 01		311 05		5 30		156 17	15
40	354 57.5	40.3	18 06.0	25 31		313 35		8 01		158 41	17
50	357 27.5	40.4	20 36.4	28 01		316 05		10 31		161 06	19
Rate	15 00.2	N0 00.9		14 59.7	N0 01.1	15 00.7	N0 00.3	15 01.9	N0 00.2	14 28.9	S0 13.9

Lat	Moon mer. pass	Diff
	h m	m
N		
72		
70		
68	24 24	91
66	23 27	
64	22 54	74
62	22 30	62
60	22 11	56
58	21 55	52
56	21 42	49
54	21 31	47
52	21 20	45
50	21 11	44
45	20 53	40
40	20 37	38
35	20 24	36
30	20 13	34
20	19 54	32
10	19 38	29
0	19 22	27
10	19 07	25
20	18 51	22
30	18 33	20
35	18 22	18
40	18 10	16
45	17 56	14
50	17 39	11
52	17 31	10
54	17 22	08
56	17 12	06
58	17 01	04
60	16 48	01
S		

Moon's P in A

A l t	C o r	A l t	C o r
°	+	°	+
0	59	54	34
4	58	55	33
11	57	56	32
15	56	57	31
19	55	58	30
21	54	59	29
24	53	60	28
26	52	62	27
28	51	63	26
30	50	64	25
32	49	65	24
34	48	66	23
35	47	67	22
37	46	68	21
39	45	69	20
40	44	70	19
42	43	71	18
43	42	72	17
45	41	73	16
46	40	74	15
47	39	75	14
49	38	76	13
50	37	77	12
51	36	78	11
52	35	79	10
54	34	80	
55			

Sun SD 16.0
Moon SD 16.1
Age 17d

(DAY 105) GREENWICH P. M. 1987 APRIL 15 (WEDNESDAY)

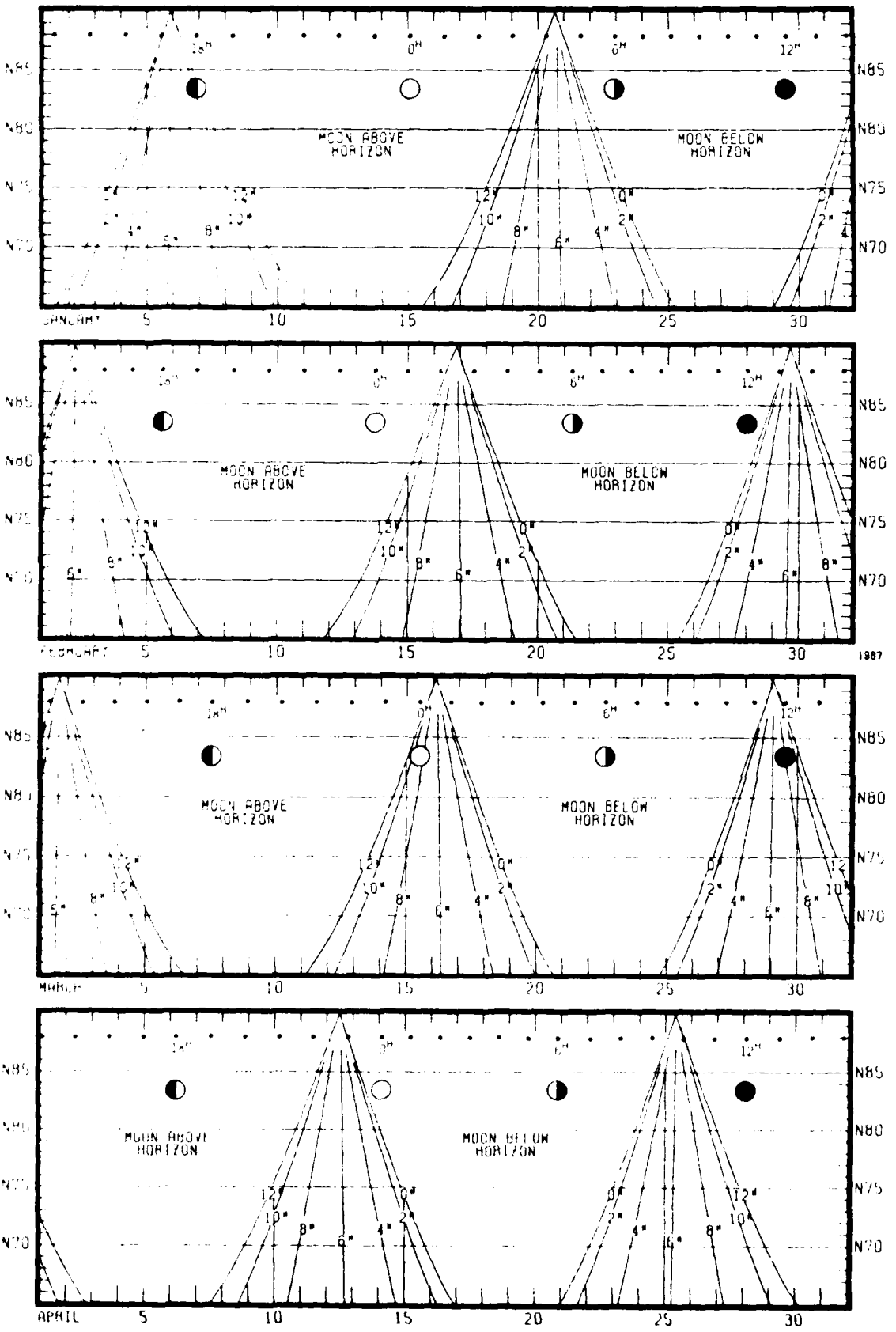
GMT UT	SUN GHA	SUN Dec	ARIES GHA	VENUS -4.0 GHA	VENUS -4.0 Dec	MARS 1.5 GHA	MARS 1.5 Dec	JUPITER -2.0 GHA	JUPITER -2.0 Dec	MOON GHA	MOON Dec
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
12 00	339 57.5	N 9 46.6	23 06.6	30 31.2	S 4 39	318 35	N22 18	14 01	N 3 10	163 31	S18 21
10	342 27.6	46.7	25 37.2	33 01.2		321 05		15 32		165 55	23
20	4 57.6	46.9	28 07.8	35 31.2		323 35		18 02		168 20	26
30	7 27.6	47.0	30 38.3	38 01.2		326 05		20 32		170 45	28
40	9 57.6	47.2	33 08.9	40 31.2		328 35		23 03		173 10	30
50	12 27.7	47.3	35 39.5	43 01.2		331 05		25 33		175 34	32
13 00	14 57.7	N 9 47.5	38 09.3	45 31.2	S 4 38	333 36	N22 18	28 03	N 3 10	177 58	S18 35
10	17 27.8	47.6	40 44.7	48 01.2		336 06		30 33		180 24	37
20	19 57.8	47.8	43 10.1	50 31.2		338 36		33 04		182 48	39
30	22 27.8	47.9	45 40.5	53 00.9		341 06		35 34		185 13	41
40	24 57.8	48.1	48 10.9	55 30.9		343 36		38 04		187 38	43
50	27 27.8	48.2	50 41.3	58 00.9		346 06		40 35		190 02	46
14 00	29 57.8	N 9 48.4	53 11.7	60 30.9	S 4 37	348 36	N22 18	43 05	N 3 10	192 27	S18 48
10	32 27.9	48.5	55 42.1	63 00.9		351 06		45 35		194 52	50
20	34 57.9	48.7	58 12.5	65 30.9		353 36		48 06		197 16	52
30	37 27.9	48.8	60 42.9	68 00.9		356 07		50 36		199 41	54
40	39 57.9	49.0	63 13.4	70 30.9		358 37		53 06		202 06	56
50	42 28.0	49.1	65 43.8	73 00.9		1 07		55 37		204 30	18 59
15 00	44 58.0	N 9 49.3	68 14.2	75 30.9	S 4 35	3 37	N22 19	58 07	N 3 10	206 55	S19 01
10	47 28.0	49.4	70 44.6	78 00.9		6 07		60 37		209 20	03
20	49 58.0	49.6	73 15.0	80 30.9		8 37		63 08		211 44	05
30	52 28.1	49.7	75 45.4	83 00.9		11 07		65 38		214 09	07
40	54 58.1	49.9	78 15.8	85 30.9		13 37		68 08		216 34	09
50	57 28.1	50.0	80 46.2	88 00.9		16 07		70 39		218 58	12
16 00	59 58.1	N 9 50.2	83 16.6	90 30.9	S 4 34	18 38	N22 19	73 09	N 3 11	221 23	S19 14
10	62 28.2	50.3	85 47.1	93 00.9		21 08		75 39		223 48	16
20	64 58.2	50.5	88 17.5	95 30.9		23 38		78 10		226 12	18
30	67 28.2	50.6	90 47.9	97 59.9		26 08		80 40		228 37	20
40	69 58.3	50.8	93 18.3	100 29.9		28 38		83 10		231 01	22
50	72 28.3	50.9	95 48.7	102 59.9		31 08		85 41		233 26	25
17 00	74 58.3	N 9 51.1	98 19.1	105 29.9	S 4 33	33 38	N22 19	88 11	N 3 11	235 51	S19 27
10	77 28.3	51.2	100 49.5	107 59.9		36 08		90 41		238 15	29
20	79 58.4	51.4	103 19.9	110 29.9		38 38		93 11		240 40	31
30	82 28.4	51.5	105 50.3	112 59.9		41 09		95 42		243 05	33
40	84 58.4	51.6	108 20.8	115 29.9		43 39		98 12		245 29	35
50	87 28.4	51.8	110 51.2	117 59.9		46 09		100 42		247 54	37
18 00	89 58.5	N 9 51.9	113 21.6	120 29.9	S 4 32	48 39	N22 19	103 13	N 3 11	250 18	S19 39
10	92 28.5	52.1	115 52.0	122 59.9		51 09		105 43		252 43	42
20	94 58.5	52.2	118 22.4	125 29.9		53 39		108 13		255 08	44
30	97 28.5	52.4	120 52.8	127 59.9		56 09		110 44		257 32	46
40	99 58.6	52.5	123 23.2	130 29.9		58 39		113 14		259 57	48
50	102 28.6	52.7	125 53.6	132 59.9		61 10		115 44		262 21	50
19 00	104 58.6	N 9 52.8	128 24.0	135 29.9	S 4 31	63 40	N22 20	118 15	N 3 11	264 46	S19 52
10	107 28.6	53.0	130 54.4	137 59.9		66 10		120 45		267 11	54
20	109 58.7	53.1	133 24.9	140 29.9		68 40		123 15		269 35	56
30	112 28.7	53.3	135 55.3	142 58.9		71 10		125 46		272 00	19 58
40	114 58.7	53.4	138 25.7	145 28.9		73 40		128 16		274 24	20 01
50	117 28.7	53.6	140 56.1	147 58.9		76 10		130 46		276 49	03
20 00	119 58.8	N 9 53.7	143 26.5	150 28.9	S 4 30	78 40	N22 20	133 17	N 3 11	279 13	S20 05
10	122 28.8	53.9	145 56.9	152 58.9		81 10		135 47		281 38	07
20	124 58.8	54.0	148 27.3	155 28.9		83 41		138 17		284 03	09
30	127 28.8	54.2	150 57.7	157 58.9		86 11		140 47		286 27	11
40	129 58.9	54.3	153 28.1	160 28.9		88 41		143 18		288 52	13
50	132 28.9	54.5	155 58.6	162 58.9		91 11		145 48		291 16	15
21 00	134 58.9	N 9 54.6	158 29.0	165 28.9	S 4 29	93 41	N22 20	148 18	N 3 12	293 41	S20 17
10	137 28.9	54.8	160 59.4	167 58.9		96 11		150 49		296 05	19
20	139 59.0	54.9	163 29.8	170 28.9		98 41		153 19		298 30	21
30	142 29.0	55.1	166 00.2	172 58.9		101 11		155 49		300 54	23
40	144 59.0	55.2	168 30.6	175 28.9		103 42		158 20		303 19	26
50	147 29.0	55.4	171 01.0	177 58.9		106 12		160 50		305 43	28
22 00	149 59.1	N 9 55.5	173 31.4	180 28.9	S 4 28	108 42	N22 21	163 20	N 3 12	308 08	S20 30
10	152 29.1	55.7	176 01.8	182 58.9		111 12		165 51		310 33	32
20	154 59.1	55.8	178 32.3	185 27.9		113 42		168 21		312 57	34
30	157 29.1	56.0	181 02.7	187 57.9		116 12		170 51		315 22	36
40	159 59.2	56.1	183 33.1	190 27.9		118 42		173 22		317 46	38
50	162 29.2	56.3	186 03.5	192 57.9		121 12		175 52		320 11	40
23 00	164 59.2	N 9 56.4	188 33.9	195 27.9	S 4 27	123 42	N22 21	178 22	N 3 12	322 35	S20 42
10	167 29.2	56.6	191 04.3	197 57.9		126 13		180 53		325 00	44
20	169 59.3	56.7	193 34.7	200 27.9		128 43		183 23		327 24	46
30	172 29.3	56.9	196 05.1	202 57.9		131 13		185 53		329 49	48
40	174 59.3	57.0	198 35.5	205 27.9		133 43		188 24		332 13	50
50	177 29.3	57.2	201 05.9	207 57.9		136 13		190 54		334 39	52
Rate	15 00.2	N0 00.9		14 59.7	N0 01.1	15 00.7	N0 00.3	15 01.9	N0 00.2	14 27.8	S0 12.7

Lat	Moon-set	Diff.
°	h m	m
N 72	02 30	8
70	03 10	8
68	03 39	-26
66	04 00	14
64	04 18	-08
62	04 32	03
60	04 44	00
58	04 55	+03
56	05 04	05
54	05 12	07
52	05 20	08
50	05 27	10
45	05 41	12
40	05 53	15
35	06 03	16
30	06 12	18
20	06 28	21
10	06 42	24
0	06 55	26
10	07 08	28
20	07 22	31
30	07 38	34
35	07 47	35
40	07 58	37
45	08 10	40
50	08 26	43
52	08 33	44
54	08 41	46
56	08 50	48
58	09 01	50
60	09 13	54
S		

Moon's P. in A

Alt	Corr	Alt	Corr
°	′	°	′
0	59	54	34
6	58	55	33
12	57	56	32
16	56	57	31
19	55	58	30
22	54	59	29
24	53	61	28
26	52	62	27
29	51	63	26
30	50	64	25
32	49	65	24
34	48	66	23
36	47	67	22
37	46	68	21
39	45	69	20
40	44	70	19
42	43	71	18
43	42	72	17
45	41	73	16
46	40	74	15
47	39	75	14
49	38	76	13
50	37	77	12
51	36	78	11
52	35	79	10
54	34	80	
55			

Sun SD 16.0
Moon SD 16.1
Age 17d


MOON ABOVE HORIZON
MOON BELOW HORIZON
N85
N80
N75
N70
5
10
15
20
25
30
1987

F4 INTERPOLATION OF MOONRISE, MOONSET

FOR LONGITUDE

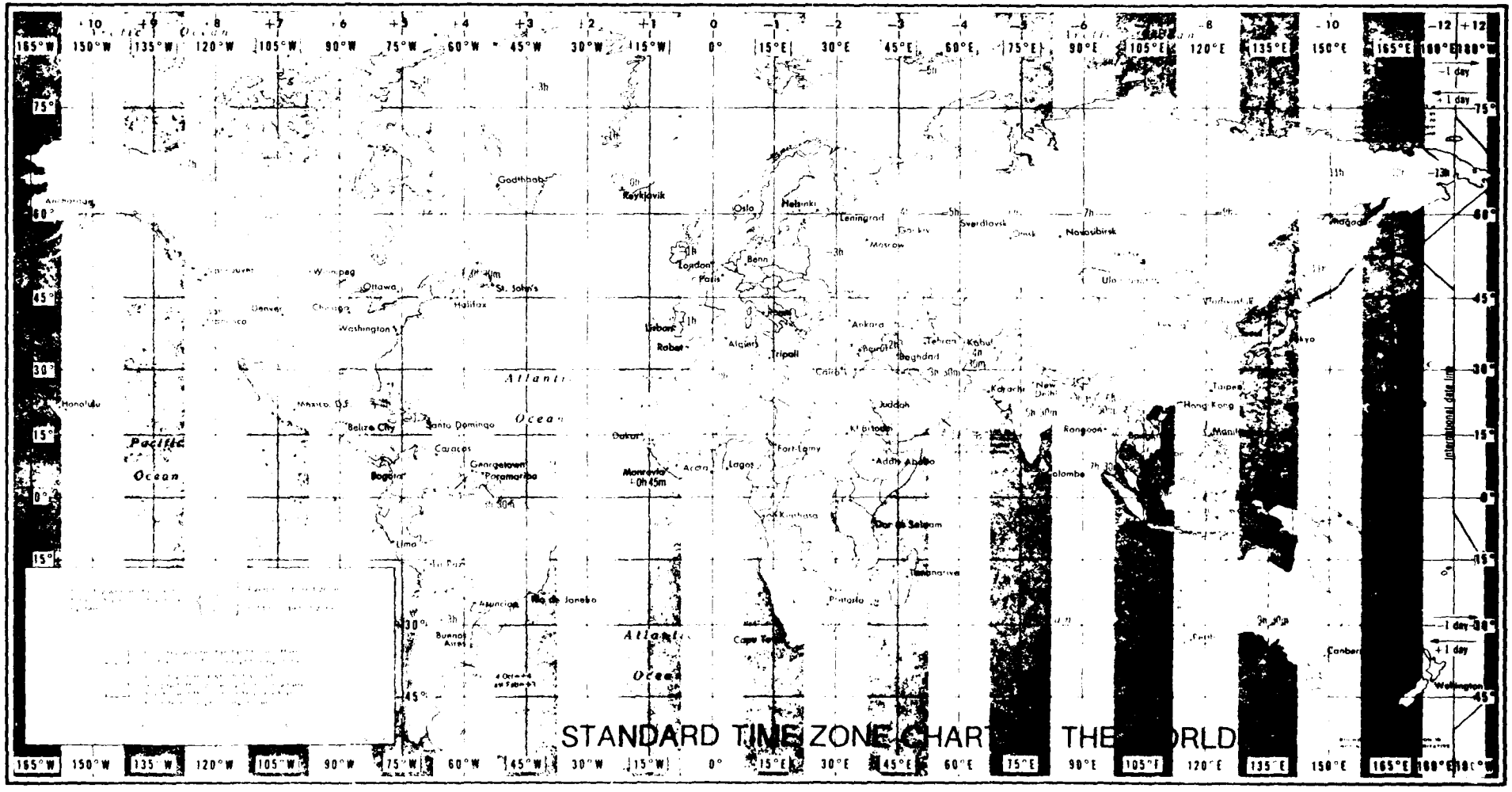
Add if longitude *west*
Subtract if longitude *east*

Longitude	Diff.*					
	05	10	15	20	25	30
°	m	m	m	m	m	m
0	00	00	00	00	00	00
20	01	01	02	02	03	03
40	01	02	03	04	06	07
60	02	03	05	07	08	10
80	02	04	07	09	11	13
100	03	06	08	11	14	17
120	03	07	10	13	17	20
140	04	08	12	16	19	23
160	04	09	13	18	22	27
180	05	10	15	20	25	30

Longitude	Diff.*					
	35	40	45	50	55	60
°	m	m	m	m	m	m
0	00	00	00	00	00	00
15	03	03	04	04	05	05
30	06	07	08	08	09	10
45	09	10	11	12	14	15
60	12	13	15	17	18	20
75	15	17	19	21	23	25
90	18	20	22	25	28	30
105	20	23	26	29	32	35
120	23	27	30	33	37	40
135	26	30	34	38	41	45
150	29	33	38	42	46	50
165	32	37	41	46	50	55
180	35	40	45	50	55	60

Longitude	Diff.*					
	65	70	75	80	85	90
°	m	m	m	m	m	m
0	00	00	00	00	00	00
10	04	04	04	04	05	05
20	07	08	08	09	09	10
30	11	12	12	13	14	15
40	14	16	17	18	19	20
50	18	19	21	22	24	25
60	22	23	25	27	28	30
70	25	27	29	31	33	35
80	29	31	33	36	38	40
90	32	35	38	40	42	45
100	36	39	42	44	47	50
110	40	43	46	49	52	55
120	43	47	50	53	57	60
130	47	51	54	58	61	65
140	51	54	58	62	66	70
150	54	58	62	67	71	75
160	58	62	67	71	76	80
170	61	66	71	76	80	85
180	65	70	75	80	85	90

* When negative *subtract* correction if longitude *west*, and *add* if *east*.


STANDARD TIME ZONE CHART OF THE WORLD
Pacific Ocean
Atlantic Ocean
Atlantic Ocean
Reykjavik
Oslo
Helsinki
Leningrad
Moscow
Sverdlovsk
Novosibirsk
London
Paris
Bonn
Ottawa
Washington
Lisbon
Rabat
Algiers
Tripoli
Ankara
Cairo
Tehran
Kabul
Baghdad
Jeddah
Karachi
New Delhi
Rangoon
Hong Kong
Taipei
Manila
Honolulu
Mexico
Belize City
Santo Domingo
Caracas
Georgetown
Paramaribo
Bogota
Lima
Dakar
Monrovia
Accra
Lagos
Fort Lamy
Addis Ababa
Kinshasa
Dar es Salaam
Tananarive
Colombo
Rio de Janeiro
Buenos Aires
Canberra
Wellington
International date line
+1 day
-1 day

Sunrise/Sunset Calculation Worksheet

I. Obtain Local Mean Time (LMT) from the tables contained in the Air Almanac, pp A130-A145. You will need the date, and the latitude of the location you desire. Some interpolation may be required.

II. Next convert the LMT from Step I to GMT by using the Conversion of Time chart on page A166. The whole degrees (°) of longitude will be converted into hours and minutes using the left column of the chart and the minutes (') of longitude will be converted into minutes and seconds using the right hand column. The times are then added (for West Longitude) to the LMT obtained in step one. The result is the time of the event in GMT.

III. Convert GMT to LST using standard correction obtained from pages A20-A23.

1. Date: _____
2. Latitude: _____
3. Longitude: _____(°) _____(') _____('')
4. Standard Time Correction +/- _____hrs ____min

5. In appropriate page from A130 -A145, At the intersection of items 1 and 2 read the Local Mean Time and enter below:

BEGIN CIVIL TWILIGHT	SUNRISE	SUNSET	End Civil Twilight
_____ LMT	_____LMT	_____LMT	_____LMT

6. From The Arc to Time Table, on page A166: Determine the GMT Conversion_____ hrs_____ min based on whole (°) longitude. Last column_____ min_____ sec based on minutes and seconds of longitude. Combining the two and rounding off seconds to minutes will give you the Total GMT Conversion (7).

7. Total GMT conversion = +/- ___Hrs____Min
(+ correction for West Longitude / - Correction for East Longitude)

8. BEGIN IN GMT-add 5 and 7
(or Civil Twilight)* (5)

	Hrs	Min	
(7) +/-	Hrs	Min	
	Hrs	Min	Z

9. BEGIN IN LST-apply standard cor.(4) to (8) (8)

	Hrs	Min	
(4) +/-	Hrs	Min	
	Hrs	Min	LST

* Civil Twilight can be computed in steps 8 and 9 using data from Civil Twilight tables. NOTE. **Nautical Twilight Time** can be estimated by subtracting the difference between civil twilight time and sunrise from Begin civil Twilight. and adding the difference between civil twilight time and sunset to the end civil twilight time.

MOONRISE/MOONSET CALCULATIONS WORKSHEET

I. Enter the Date, and the latitude/longitude of the location in question on the worksheet below.

II. Using the information from step I determine the Moonrise/set time from the appropriate Air Almanac table (pp 1-732) for the date in question. Some interpolation will be required. This is the Local Mean Time of the event at 0° Longitude. At the same time, copy down the DIFF value from the latitude closest to your location.

III. To convert to local mean time for your location, Enter page F4, using the longitude and the Diff from step II to determine the correction to be applied to LMT. After applying the correction and you will have the local mean time of the event for your location.

IV. Convert to GMT using the procedures below in para 9.

V. Convert to LST using the procdeures in para 10 (The Standard Correction (5) obtained from pages A20-A23 of the Air Almanac.

1. Date: _____
2. Latitude: _____
3. Longitude: _____(°)_____(')_____('')
4. Diff value(s) _____/_____minutes
5. Standard Time Correction _____+/- hrs

6. Using 1 and 2 determine moonrise/set times at 0° Longitude from pp 1-732. MR:_____/MS:_____.

7. Using 3 and 4 determine the correction for your longitude and apply to the time arrived at in 6. MR_____/MS_____.

8. From The Arc to Time Table, on page A166: Determine the GMT Conversion on the left side of the chart _____ hrs_____ min based on whole (°) longitude. From the last column determine the _____min _____sec based on minutes and seconds of longitude. Combining the two and rounding off seconds to minutes will giv you the Total GMT Conversion (8).

9. Total GMT conversion = +/-_____Hrs____Min
(Use a + correction for West Longitude ; a - Correction for East Longitude)

10. MR/MS IN GMT-(add 7 and 9)

	(7)		Hrs	Min
	(9)	+/-	Hrs	Min
			Hrs	Min

11. MR/MS IN LST-apply standard cor. to (10)

	(10)		Hrs	Min
	(5)	+/-	Hrs	Min
			Hrs	Min

PREPARATION OF ASTRONOMICAL DATA - TEST ANSWERS

1. The earth's axis is not perpendicular to the plane of it's orbit. It is tilted 23 1/2°. (or words to that effect.)

2. AM Civ Twilight | Sunrise | Sunset | PM Civ Twilight
   0505 | 0532 | 1840 | 1907

3. AM Civ Twilight | Sunrise | Sunset | PM Civ Twilight
   0304 | 0444 | 1924 | 2104

4. A. The moon's orbital speed
   B. The moon's orbital angle } (in either order)

5. Moonrise | Moonset
   2035 GMT | 0449 GMT
   2135 LST | 0549 LST

6. Moonrise | Moonset
   7 May /0645 | 8 May /0645

If you missed any of these questions, go back and reread the appropriate sections of this Tech Note.

END
DATE
FILMED
5-88
DTIC